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Nitrogenous Fertilizers for Growing Tobacco

By A. B. Beaumont and M. E. Snell

In the many years that tobacco has been grown in the Connecticut Valley, certain fertilizer practices have been adopted. This study was undertaken to provide a research basis for those practices which are considered sound.

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NITROGENOUS FERTILIZERS FOR GROWING TOBACCO

By A. B. Beaumont and M. E. Snell[1]

Herein are reported the results of four experiments with tobacco in which the nitrogenous component of the fertilizer used or the method of its application was the variable factor. Specifically, the effects of the following factors on yield and grading quality were studied:

1. Quantity of nitrogen applied.
2. Form of nitrogen applied.
3. Ratio of organic to inorganic nitrogen.
4. Method of applying fertilizer.

The type of tobacco, soil, and general field technic used in these experiments were the same as or closely similar to those used in experiments with cropping systems for tobacco, described in a previous bulletin of this station (4 . Such supplemental details as are necessary for an understanding of the work are presented later in connection with the report on the several experiments.

Quantity of Nitrogen Applied in Fertilizer[2]

This experiment was started in a preliminary way in 1926. In that year it included a variation in the method of topping tobacco, and therefore the results of 1926 are not included in this report although they were in general alignment with those of the later years, 1927 – 1931. The fertilizer used carried 140 pounds of phosphoric acid (P_2O_5) supplied by precipitated bone; and 175 pounds of potash (K_2O) of which 26.7 pounds came from cottonseed meal, and the rest was equally divided between sulfate of potash-magnesia and nitrate of potash. The nitrogen in the fertilizer came from the following sources: ½ from cottonseed meal, ¼ from calurea, about 1/7 from nitrate of potash, and the remainder from nitrate of soda. Nitrogen was applied at the following rates: 61.8, 123.5, 164.7, and 205.9 pounds per acre.[3] These plots were in quadruplicate and were one fortieth of an acre in size.

The yield and grade of cured tobacco produced in this experiment for the years 1927–1931 inclusive are presented in Table 1, and shown graphically in Figure 1. The average yields from the different quantities of nitrogen show diminishing returns with increasing amounts, as was to be expected. The yield curve shows the typical sigmoid form for plant growth. Extrapolation of this curve indicates that the maximum yield might be expected with an application of about 250 pounds of nitrogen.

The curve for the grade index is of the same general type as that for yields, but the maximum was reached with the application of 164.7 pounds. From that point on, the grading quality of the tobacco diminished fairly rapidly. The explanation of this decrease is to be seen in the percentage of the different grades shown in Table 1. The percentage of "lights" (L), "mediums" (M), and "long seconds" (LS), the most influential grades in determining the grade index, taken collectively, increased about 43 percent between the lowest and second highest quantity of nitrogen, and then decreased about 5.4 percent between this point and the maximum quantity of nitrogen. The percentage of "darks," taken collectively, steadily but slowly increased between the lowest and highest quantities of nitrogen, although the percentage of "long darks" reached a maximum with 164.7 pounds. Collectively, the percentage of "seconds" did not vary a great deal from one treatment to another, although there was a steady and marked increase in the percentage of "long seconds" from the lowest to the highest amount of nitrogen. The percentage of "fillers" and "brokes" decreased from the lowest to the highest quantity of nitrogen, but there was little decline in the percentage of these grades between the next highest and highest quantities.

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[1] Formerly Professor of Agronomy and Technical Assistant, respectively.

[2] This experiment was planned and conducted from 1926 through 1929 by Dr. J. P. Jones.

[3] When the experiment was started it was common usage to express the nitrogen content of fertilizers in terms of ammonia (NH3). The amounts of nitrogen used correspond respectively to 75, 150, 200, and 250 pounds of ammonia.

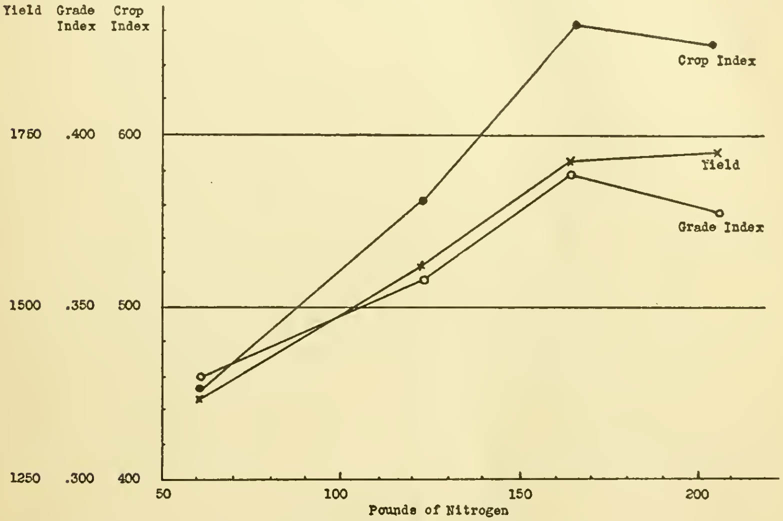

Figure 1. Variations in Yield, Grade Index, and Crop Index of Tobacco with Increasing Quantities of Nitrogen.

Since the market value of a cigar-wrapper type of tobacco such as was grown in this experiment is determined not only by the grade index but also by the size of the crop, the crop index, which is the product of yield in pounds per acre and the grade index, must be taken as the final criterion in adjudging the economic value of a given factor of production. It may be seen from the table and graph that the maximum crop index was reached with the second highest quantity of nitrogen, 164.7 pounds. The first increment of nitrogen raised the crop index 23.9 percent, and the second increased it 18.9 percent. However, the nitrogen increments were not equal, and, as the graph shows, the rate of increase was slightly greater with the second than with the first increment.

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TABLE 1. — YIELD AND GRADE OF TOBACCO GROWN WITH DIFFERENT QUANTITIES OF NITROGEN

Year	*Percentage of Grades*								*Grade Index**	*Yield Pounds per A.*	*Crop Index**
	L	*M*	*LS*	*SS*	*LD*	*SD*	*F*	*B*			
61.8 pounds Nitrogen											
1927	1.9	2.9	14.7	3.0	26.0	14.2	19.6	17.7	.277	1371	379.8
1928	5.2	5.7	6.3	17.0	20.0	22.2	16.2	7.4	.303	1062	321.8
1929	0.9	2.4	12.2	15.2	32.1	16.7	12.5	8.0	.292	1340	391.3
1930	4.3	14.3	22.8	14.6	21.0	11.1	7.8	4.1	.407	1505	612.5
1931	0.6	4.9	23.7	19.0	35.9	11.5	4.1	0.3	.370	1513	559.8
Average	2.6	6.0	15.9	13.8	27.0	15.2	12.0	7.5	.330	1358.2	453.0
123.5 pounds Nitrogen											
1927	2.4	4.3	16.9	4.0	36.2	9.2	12.7	14.3	.317	1679	532.2
1928	0.5	6.3	13.1	19.3	32.1	14.2	11.3	3.2	.319	1260	401.9
1929	2.4	3.2	24.8	10.0	34.2	11.3	8.7	5.4	.361	1535	554.1
1930	2.6	18.3	17.7	17.3	22.1	11.3	8.2	2.5	.394	1608	633.6
1931	1.4	12.5	20.5	17.6	39.6	4.9	2.6	0.9	.397	1727	685.6
Average	1.9	8.9	18.6	13.6	32.8	10.2	8.7	5.3	.358	1561.8	561.5
164.7 pounds Nitrogen											
1927	0.9	6.4	21.7	3.2	43.5	7.6	8.1	8.6	.350	1700	595.0
1928	0.5	10.0	17.3	16.4	34.6	10.2	8.4	2.6	.353	1294	456.8
1929	0.9	5.1	20.8	9.1	44.9	4.5	8.4	6.2	.350	1702	595.7
1930	8.7	24.9	19.6	11.7	22.2	5.0	4.4	3.5	.474	1881	891.6
1931	1.1	10.9	26.2	13.6	42.0	3.2	2.6	0.4	.410	1953	800.7
Average	2.4	11.5	21.1	10.8	37.4	6.1	6.4	4.3	.387	1706.0	668.0
205.9 pounds Nitrogen											
1927	0	4.5	20.4	2.1	46.5	8.5	8.1	10.0	.330	1743	575.2
1928	1.5	6.0	22.8	16.7	31.3	11.8	8.1	1.8	.365	1337	488.0
1929	1.0	3.6	18.3	12.6	44.6	6.8	8.2	4.9	.340	1709	581.1
1930	5.1	21.7	20.9	13.9	22.5	8.7	4.9	2.3	.440	1810	796.4
1931	0.6	11.7	27.8	12.8	40.1	3.5	2.7	0.8	.412	2025	834.3
Average	1.6	9.5	22.0	11.6	37.0	7.9	6.4	4.0	.377	1724.8	655.0

* Grade index, as used here, is a number expressing the grading quality of tobacco produced under the conditions of the experiment. It is based upon the percentage yield of each grade of tobacco and the relative values of these grades of tobacco, given below:

Lights	1.00	Long darks (19″ and longer)	.30
Mediums	.60	Dark stemming (17″ and shorter)	.20
Long seconds (19″ and longer)	.60	Brokes	.10
Short seconds (17″ and shorter)	.30	Fillers	.10

The grade index is derived by multiplying the percentage of each grade of tobacco by the respective rating of the grades, given above, and adding the products.

Crop index, as used here, is a number expressing the crop value of tobacco produced under the conditions of experiment. It is based upon the gross yields of tobacco in pounds per acre and the grade index of the tobacco. Crop index is derived by multiplying the gross yield of tobacco in pounds per acre by the grade index of the tobacco.

Grade index and crop index and the adopted relative values of the different grades of tobacco, as used here, do not necessarily represent current commercial prices of tobacco.

According to experiments conducted at the Connecticut Experiment Station (9), an average crop of Havana Seed tobacco, comparable in yield and grading quality to those grown in the present experiment, removes from the soil 114 pounds of nitrogen. This is the total amount removed by the entire plant — leaves, stalk, and roots. The question then naturally arises as to why it is necessary to apply as much as 164.7 pounds of fertilizer nitrogen in order to get an optimum crop. Besides the nitrogen applied in the fertilizer, the soil contains several hundred pounds of organic nitrogen per acre, part of which becomes available during the growing season through the process of nitrification. In this experiment a cover crop of oats was sown each year following the harvest of the tobacco crop.

Nitrates were determined in soil samples taken from the plots receiving the different quantities of nitrogen. The average concentration of nitrate nitrogen for July, the month of greatest intake of nitrogen by the crop, was as follows:

Pounds of Nitrogen Applied	*Nitrate Nitrogen (N) in parts per million of dry soil*	
	1930	*1931*
61.8	43.0	32.6
123.5	53.7	53.6
164.7	74.9	64.9
205.9	74.7	67.6

From Table 1 it may be seen that 1930 and 1931 were the years of the best yield and quality of tobacco in this experiment. Thus, it appears necessary to maintain through July a fairly high (65–75 p.p.m.) level of nitrate nitrogen in order to insure optimum quality and high yield. The plants do not absorb all this available nitrogen. Although tobacco has an extensive root system, the roots do not occupy the soil sufficiently to withdraw all the available nitrogen. In the north temperate zone, nitrates are almost invariably found in soil growing intertilled crops. It is only in soil more completely occupied by the roots of a crop such as grass that nitrates are not found in the growing season. The soil on which the present experiment was run was underlaid by gravel, and it is assumed, therefore, that a considerable proportion of soluble nitrogen was lost in the drainage water. Some of it remained in the soil to be absorbed by cover crops, weeds, and lower organisms of the soil.

Burn tests made on "darks" and "seconds" of the crops of 1930 and 1931 showed no consistent differences in the burn of the darks, but the burn of the seconds was slightly better from the plots which received 164.7 pounds of nitrogen than from any other treatment.

Form of Nitrogen Applied

Long-established fertilizer practice in the Connecticut Valley has sanctioned the use of a mixed fertilizer containing a high percentage of organic nitrogenous material, particularly cottonseed meal. Inorganic sources of nitrogen have generally been frowned upon by tobacco growers, and certain forms have been studiously avoided. No doubt part of the aversion of the growers to inorganic nitrogen is well founded in experience.

This experiment was planned for the purpose of determining the effect of two of the more common inorganic and two of the synthetic organic forms of nitrogen on the yield and grade of tobacco when one half the total nitrogen was supplied by these forms and the other half by cottonseed meal. Nitrogen was used at the rate of 175 pounds to the acre. The phosphoric acid and potash were from the same sources and at the same rates as those used in the first experiment, except that high grade sulfate of potash was used instead of nitrate of potash. The standard mixture, also, was of the same composition as in the first experiment except that the amount of nitrogen was uniformly at the rate of 175 pounds. This experiment, as were the others reported in this bulletin, was run with quadruplicated plot treatments, and plots were also one fortieth acre in size. The mean of the yield, grade index, and crop index for four years is given in Table 2.

Table 2. — Mean yield and grade of tobacco grown with different nitrogen carriers supplying one-half the nitrogen, 1932–1935

Carrier	*Yield, Lbs./A*	*Grade Index*	*Crop Index*
Nitrate of soda	1876.0	.410	769.8
Sulfate of ammonia . .	1851.5	.392	726.3
Calcium cyanamid . . .	1863.0	.399	746.5
Urea	1843.3	.400	738.1
Standard Mixture . . .	1889.8	.402	761.3

The differences shown are not considered significant, although a strong trend is indicated in favor of tobacco supplied with nitrate of soda over that grown with other forms of nitrogen. Little superiority is shown by the treatment containing nitrate of soda over the standard mixture, as reflected in the crop index. The difference is due to the grade index, not the yield, which is slightly higher from the standard mixture. It should be noted, however, that the standard mixture contained considerable nitrate nitrogen both in nitrate of soda and nitrate of potash.

Calcium cyanamid produced the highest yield and best grade of tobacco the first year. In the following years nitrate of soda produced the best grade and highest yield, except for one year when it was exceeded by the standard mixture. The grading quality of tobacco fertilized with sulfate of ammonia suffered more than did the yield. Calcium cyanamid and urea were erratic in their effects. However, all treatments produced tobacco of better than average yield and grade throughout the experiment as a whole.

The effect of fertilizer treatment on burning quality of the tobacco is shown in Table 3. The comparatively poor fire-holding capacity of tobacco fertilized with sulfate of ammonia conforms with results of experiments conducted elsewhere and with practical experience. Nitrate of soda showed marked superiority in its effect on burn, and most likely the nitrate content of the standard mixture contributed to the good effect of that fertilizer. It is not known from the present experiment whether the beneficial effect of the nitrate was direct, in the sense that it increased the nitrate content of the leaf, or whether its beneficial action was primarily indirect. Experiments conducted at the Connecticut Experiment Station (1) showed that tobacco leaves containing potassium nitrate gave perfect fire-holding capacity, but high concentrations produced a black ash and an undesirable sputtering and sparkling.

TABLE 3. — MEAN BURN IN SECONDS OF TOBACCO GROWN WITH DIFFERENT NITROGEN CARRIERS SUPPLYING ONE-HALF THE NITROGEN, 1932–1934

Carrier	*Darks*	*Seconds*
Nitrate of soda	12.3	30.5
Sulfate of ammonia	8.3	13.8
Calcium cyanamid	10.3	14.2
Urea	9.5	20.0
Standard mixture	13.3	23.0

The possible relation of form of fertilizer nitrogen to degree of infestation of brown root-rot of tobacco was studied. The percentage of infection was determined by random sampling, and the results are given in Table 4. No consistent differences due to treatment were noted. If, as has been suggested by one of the authors, brown root-rot of tobacco is caused by the rapid absorption of unoxidized forms of nitrogen, it appears from the present experiment that the form of fertilizer nitrogen used is in itself an unimportant factor. The nature of the preceding crop and the amount and distribution of rainfall appear to be the dominant factors affecting brown root-rot.

TABLE 4. — PERCENTAGE OF BROWN ROOT-ROT IN TOBACCO GROWN WITH DIFFERENT NITROGEN CARRIERS SUPPLYING ONE-HALF THE NITROGEN, 1932–1935

Carrier	*1932*	*1933*	*1934*	*1935*	*Mean*
Nitrate of soda	45.0	58.0	4.0	37.0	36.0
Sulfate of ammonia	30.0	82.0	16.0	38.5	41.6
Calcium cyanamid	25.0	76.0	4.0	36.5	35.4
Urea	75.0	76.0	0.0	37.0	47.0
Standard mixture	60.0	78.0	0.0	38.5	44.1

The change in reaction of the soil used in this experiment during its course was as follows:

Form of Nitrogen Applied	*pH at Beginning of Experiment*	*pH at End of Experiment*
Nitrate of soda	5.25	5.75
Sulfate of ammonia	5.1	5.1
Calcium cyanamid	5.3	5.5
Urea	5.0	5.3
Standard mixture	5.1	5.4

The fact that, according to these figures, sulfate of ammonia and urea did not lower the reaction, suggests that because of a seasonal difference in time of sampling, all the values in the second column are a little high. Long-continued use of these fertilizer materials would no doubt accentuate differences here indicated and possibly produce soil conditions unfavorable to the best growth of tobacco.

Ratio of Organic to Inorganic Nitrogen in Fertilizer

As previously stated, good fertilizer practice in the growing of tobacco in the Connecticut Valley has demanded a fertilizer containing a high percentage of organic nitrogen. The organic nitrogen carrier in demand has been a seed meal, preferably cottonseed meal. Animal sources, such as tankage, meat meal, or fish meal, have not been considered satisfactory. The special virtue of cottonseed meal lay in its ability to produce tobacco of good quality, but the peculiar properties of this material which made it capable of producing tobacco of fine quality were not well understood.

In the light of comparatively recent discoveries in plant nutrition, it now appears that the virtue of cottonseed meal in producing tobacco of high quality is due to two qualities. First, being a difficultly soluble organic material, it must undergo decomposition in the soil before its nitrogen becomes available for plant growth. This process continues through all or most of the growing season, and insures abundant nitrates in the soil at critical growth periods. Researches at this station (5) have proved that cottonseed meal is not utilized by the tobacco plant until it is decomposed. Nitrates, the final end product of protein decomposition, were found to be the form of nitrogen most readily assimilated by tobacco. Second, in recent years it has been discovered (6) that Connecticut Valley tobacco soils are frequently deficient in available magnesium unless it has been supplied artificially, and that tobacco is one of the plants most sensitive to magnesium deficiency. Cottonseed meal, in quantities in which it has been used for growing tobacco in the Valley, carries sufficient magnesium to make up for the natural deficiency of the soil, and that, no doubt, is one reason why it has produced good tobacco. But now that the need of magnesium in the Valley soils has been demonstrated, cheaper and satisfactory inorganic sources have been developed. Possibly there are other properties of cottonseed meal besides those mentioned which contribute to its value as a tobacco fertilizer.

The present experiment was undertaken for the purpose of seeing to what extent, if any, the proportion of organic nitrogen in the tobacco fertilizer could be reduced below that in the standard formula without reducing yield or impairing quality materially. The phosphoric acid and potash of the fertilizer were the same as in that used in the previously mentioned experiments. Plots were also of the same size and in quadruplicate. The organic source of nitrogen was cottonseed meal, and the inorganic sources were mixtures of nitrate of soda and sulfate of ammonia in such proportions as to furnish equal quantities of nitrogen. It is not claimed that this is the best combination of nitrogenous fertilizers, but from the previous experiment it was considered safe. It is quite possible that more nitrate and less sulfate, or the addition or substitution of urea or calcium cyanamid would have produced a better mixture. The results of this experiment are summarized in Tables 5 and 6.

TABLE 5. — MEAN YIELD AND GRADE OF TOBACCO GROWN WITH FERTILIZER IN WHICH THE RATIO OF ORGANIC TO INORGANIC NITROGEN VARIED, 1932–1935

Percentage of Total Nitrogen as Organic	*Yield Pounds*	*Grade Index*	*Crop Index*
12.5	2027.5	.394	801.5
25.0	1922.0	.394	756.2
37.5	1979.0	.388	771.4
50.0	1990.0	.392	793.5
50.0*	2020.5	.400	812.8

*Standard mixture fertilizer

TABLE 6. — MEAN BURN IN SECONDS OF TOBACCO GROWN WITH FERTILIZER IN WHICH THE RATIO OF ORGANIC TO INORGANIC NITROGEN VARIED, 1932–1934

Percentage of Total Nitrogen as Organic	*Darks*	*Seconds*
12.5	14.4	26.5
25.0	16.3	24.5
37.5	17.0	26.5
50.0	15.2	34.0
50.0*	15.9	33.5

*Standard mixture

This experiment was conducted through a period of good tobacco-growing seasons, and the average yield and quality are high with all treatments. A cover crop of oats was grown each year following the harvest of tobacco and was plowed under the following spring. This annual supply of organic matter may have been an important factor in the outcome of the experiment. In view of previous experiments (4) conducted on the same soil type in an adjoining field, the differences shown in Table 5 are no considered significant. The important point to be gained from the data is that neither yield nor grade suffered materially by reducing the percentage of organic nitrogen to one fourth that of the standard mixture. However, Table 6 indicates that the fire-holding capacity of the leaf decreased slightly as the percentage of organic nitrogen decreased. This is in line with theory already advanced.

Method of Applying Fertilizer

It has long been the custom in the Connecticut Valley to broadcast tobacco fertilizer on partially prepared land and harrow it into the soil with a smoothing harrow. This is done in advance of setting the plants, preferably about a week before. Tobacco plants are then set by a machine. Mixed fertilizer is used at the rate of 3,000 to 4,000 pounds per acre.

The purpose of this experiment was to see whether, by applying the fertilizer in bands near the plants, the rate of application could be reduced without materially reducing yield and quality of the tobacco. Previous experiments conducted at this station with corn (7) had shown an advantage of row application of fertilizer over broadcasting, but the rates per acre were smaller than are used for tobacco in the Valley.

The experiment was started in a preliminary way in 1930. In that year and again in 1931 the row applications were made in an open furrow, and were mixed into the soil by means of a heavy log chain which was dragged through the furrow. Experiments with corn and other crops (7) had shown that in general the best placement for fertilizer was in bands on each side of the seed but not in contact with it. The tobacco transplanter regularly used in experimental work, and of the same make as that commonly used by Connecticut Valley farmers, was so altered that it placed the fertilizer in two parallel bands 3 inches wide and 3 inches apart, about 1.5 inches beneath the surface of the soil.[4] Thus the plants were about 1.5 inches from each band of fertilizer. By this method the fertilizer was applied and the plants set in one

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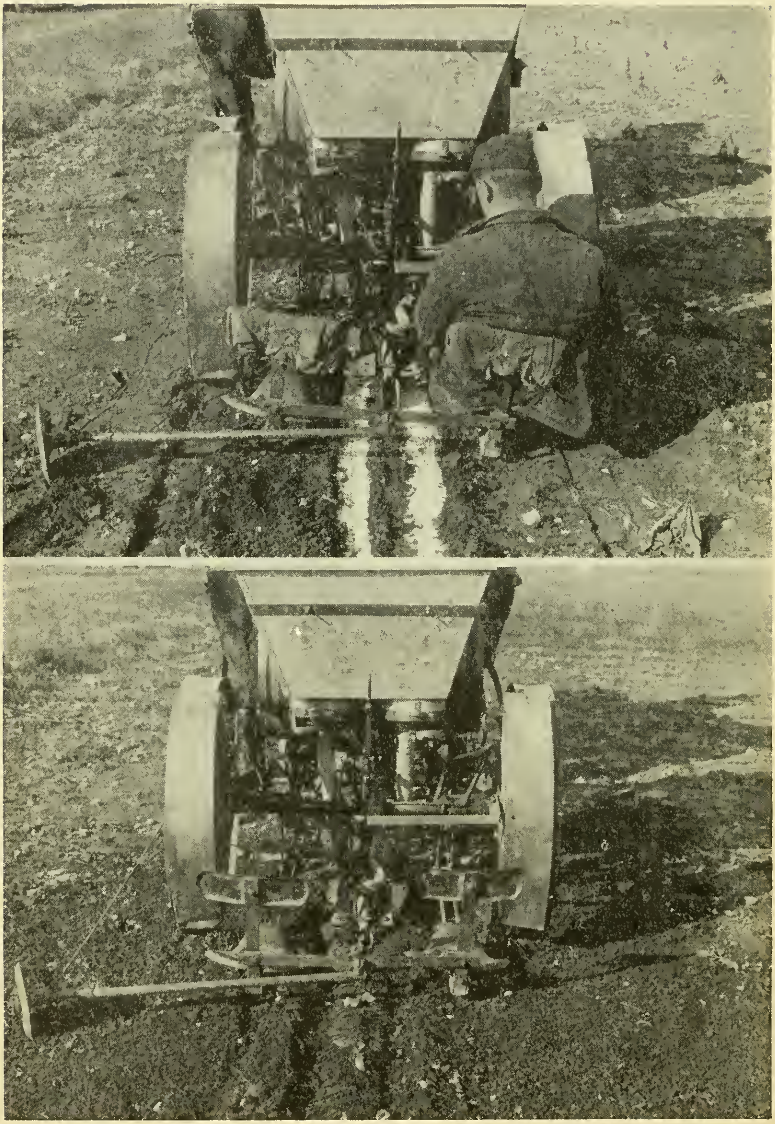
[4] The construction of the special fertilizer attachment was under the direction of Professor C. I. Gunness, Head of the Department of Agricultural Engineering. A hopper was built, to which were attached hose lines which carried the fertilizer to specially constructed "shoes."



Tobacco Transplanter with Special Attachments for Row Placement of Fertilizer

UPPER: Covering shoe removed and lime substituted for fertilizer, to show position and width of fertilizer bands.

LOWER: Covering shoe in place, fertilizer covered, and tobacco plants set.

operation. From 1932 to 1935, inclusive, the experiment was conducted with the modified planter, with results shown in Table 7. The results for the preliminary period were in general agreement with those of 1932 and 1933.

This experiment was so laid out that a check plot on which the fertilizer was broadcast was adjacent to each plot on which fertilizer was applied in the row. These plots were in quadruplicate but were only one eightieth of an acre in size. Previous to this experiment the field had been used for tobacco experiments in which all the fertilizer was broadcast at the rate of 3,500 pounds per acre. There was, therefore, a fertilizer residue in the soil, which no doubt influenced the results of the present experiment. The fertilizer used was the standard mixture referred to in the other experiments, and contained 5 percent nitrogen, 4 percent phosphoric acid, and 5 percent potash. The rate of application on the check plots was 3,500 pounds per acre, and the row-treated plots received fractions of this amount as indicated in Table 7.

For the first two years in which the fertilizer was applied by machine (1932 and 1933), the average crop index of tobacco from all row applications slightly exceeded the average from all broadcast treatments. Beginning with 1934, which was the fifth year of the experiment as a whole, the broadcast treatments produced best results. In 1932 and 1933 comparable experiments were conducted on near-by private farms, and the results closely paralleled those obtained on the station plots.

TABLE 7. — EFFECT OF METHOD OF FERTILIZER APPLICATION ON YIELD AND GRADE OF TOBACCO

Year	*Treatment*	*Yield Pounds per A.*	*Grade Index*	*Crop Index*
1932	4/8 Standard amount in row	1846	.377	699.4
	Standard amount broadcast (check)	1822	.363	664.2
	5/8 Standard amount in row	1732	.360	662.7
	Standard amount broadcast (check)	1855	.354	658.8
	6/8 Standard amount in row	1861	.375	699.5
	Standard amount broadcast (check)	1881	.381	716.2
1933	4/8 Standard amount in row	1782	.388	695.9
	Standard amount broadcast (check)	1900	.384	729.2
	5/8 Standard amount in row	1778	.405	720.6
	Standard amount broadcast (check)	1801	.395	710.1
	6/8 Standard amount in row	1885	.395	746.6
	Standard amount broadcast (check)	1851	.377	698.3
1934	4/8 Standard amount in row.	1737	.396	687.7
	Standard amount broadcast (check)	2032	.417	848.8
	5/8 Standard amount in row	1759	.402	706.3
	Standard amount broadcast (check)	2022	.419	847.1
	6/8 Standard amount in row	1798	.384	693.0
	Standard amount broadcast (check)	1994	.394	786.4
1935	4/8 Standard amount in row	1743	.371	647.9
	Standard amount broadcast (check)	2086	.401	836.3
	5/8 Standard amount in row	1708	.395	674.9
	Standard amount broadcast (check)	1994	.416	830.3
	6/8 Standard amount in row	1874	.388	727.1
	Standard amount broadcast (check)	2128	.403	855.3

These results indicate that with soil of the kind used in this experiment, which has been heavily fertilized for a number of years, a reduction of ¼ to ⅜ of the fertilizer can be made by using row, instead of broadcast, application, for a period of 2 to 4 years. After that time, both yield and quality are likely to decline with the reduced quantities.

This experiment, as have others, showed that pound for pound fertilizer placed near the plant was more effective than fertilizer broadcast. In the practical application of the results, however, one must consider several factors. Is the return on each dollar invested in fertilizer as important as the return per acre of crop? If the cost of fertilizer is high and the price of tobacco low, it may be profitable to reduce the amount of fertilizer used by resorting to row application; whereas, if the reverse relation holds, it would probably be unwise to economize in the quantity of fertilizer. In the last analysis the question is an economic one. In view of results of experiments elsewhere, it is quite probable that a combination of broadcasting and row application of fertilizer might give better results than either method alone.

General Discussion

These experiments were conducted through a period when there was a considerable variation in the rainfall during the growing season of tobacco. In Table 8 are given figures for the rainfall in May and the summer months of the years of the experiments. The tobacco plants were usually set in the field about the first of June and harvested about the third week in August.

Table 8. — Precipitation at Amherst, Massachusetts

	Normal	*1927*	*1928*	*1929*	*1930*	*1931*	*1932*	*1933*	*1934*	*1935*
May	3.63	4.83	3.25	4.17	3.34	7.44	1.67	1.69	3.42	2.17
June	3.54	3.37	6.97	3.06	4.47	4.24	2.62	3.68	4.67	5.50
July	4.33	3.40	6.23	.70	4.50	3.87	3.83	2.25	1.73	3.10
August	4.24	5.01	8.40	1.54	1.82	6.57	2.67	6.63	3.02	.82
Total (June, July, August)	12.11	11.78	21.60	5.30	10.79	14.68	9.12	12.56	9.42	9.42

Tobacco of lowest yield and poorest grading quality was produced in 1928 when the summer months were abnormally wet. In 1929, a year of summer drouth, yield was relatively lower than quality. The best yield was produced in 1931, a year of summer rainfall slightly in excess of the normal; but the best quality was obtained in 1930 when a comparatively dry August followed a nearly normal July, a wet June, and a practically normal May.

The experiment with the different quantities of nitrogen is hardly comparable with others which have been reported, because of difference in type of tobacco, soil conditions, climate, etc. For example, Garner and his associates (8) reported experiments conducted in southern Maryland, with different quantities of nitrogen applied to Maryland broadleaf tobacco. The maximum quantity of nitrogen used was 80 pounds per acre, which gave only a small increase over 40 pounds.

The conditions and practices of tobacco culture most comparable with those of the present experiment are to be found at the Tobacco Experiment Station of Connecticut. This station has reported (2) the results of the first three years of an experiment with different quantities of fertilizer nitrogen. Nitrogen was applied at the rates of 100, 150, 200, 250, and 300 pounds per acre. The results were generally similar to those reported in this bulletin. The highest yield was obtained from the largest quantity of nitrogen, but the highest grade index was obtained from an intermediate quantity, namely 200 pounds.

The experiment with the different forms of nitrogen supplying one half the nitrogen while the other half was supplied by cottonseed meal shows that, with the possible exception of ammonium sulfate, any one of the carriers used in the experiment may safely be used to supply at least one half the nitrogen of tobacco fertilizer for a limited period. This statement assumes soil and other conditions closely similar to those under which the experiment was conducted. The excellence of nitrate of soda was shown, which was reflected mainly in the grade index. This evidence should tend to dispel the prejudice against this form of nitrogen which is held in some quarters of the Connecticut Valley.

The results of the experiment with different ratios of organic and inorganic sources of nitrogen are very interesting as showing to what extent the proportion of organic nitrogen may be reduced without reducing the yield and grading quality of the crop. On the basis of only four years' data we are not convinced that it would be sound practice to reduce the percentage of organic nitrogen to the low point (12.5) indicated. However, from this and other experiments conducted at this station, it appears entirely safe to reduce the proportion of organic nitrogen to one half. Very likely, on soils of medium and heavier texture, and when cover crops are grown to supply organic matter, the content of organic matter in the fertilizer may well be reduced to one fourth.

Inorganic nitrogen and that in the synthetic organic forms such as calcium cyanamid and urea are generally much cheaper, pound for pound, than that in the natural organic forms such as cottonseed meal. Obviously, it is to the advantage of the grower to substitute the cheaper forms of nitrogen in his fertilizer when it can be done without materially reducing the value of the crop. From 1926 to 1936 the average percentage of water-insoluble organic nitrogen in mixed tobacco fertilizers sold in Massachusetts decreased from 56.6 percent to 50.4 percent, this decrease being due primarily to the substitution of the water-soluble organic forms. In view of the results from the present experiments, this trend in the source of nitrogen in tobacco fertilizer appears to be in the right direction.

The response to row application of fertilizer was less marked than was expected in view of results from an earlier and similar experiment with corn (7). In the latter experiment, however, fertilizer was used at a much lower rate than with tobacco, and this probably accounts for the difference in the results. Special attention is directed to the attachments devised for row placement of fertilizer in this experiment. By means of these it was possible to place the fertilizer accurately and easily in the desired position. The machine has possibilities for use with other plants than tobacco.

Summary and Conclusions

Four experiments were conducted in the use of nitrogenous fertilizers in growing Havana Seed tobacco, a cigar-wrapper type. The effects of the following factors on yield and grading quality were studied: 1. Quantity of nitrogen applied. 2. Form of nitrogen applied. 3. Ratio of organic to inorganic nitrogen. 4. Method of applying fertilizer. The results of the experiments are summarized as follows:

1. Nitrogen was applied at the rate of 61.8, 123.5, 164.7, and 205.9 pounds per acre. The highest average yield of tobacco was obtained from the largest quantity of nitrogen, but the highest grade index resulted from the use of 164.7 pounds. The crop index, the product of yield times grade index, by means of which the crops were evaluated, was highest for this rate (164.7) also.

2. Four forms of nitrogen, as found in nitrate of soda, sulfate of ammonia, calcium cyanamid, and urea, were compared with each other and with that in a standard mixture. Only one half the nitrogen in the fertilizer was supplied by these carriers, the remainder coming from cottonseed meal. Nitrate of soda gave the best results as measured by the crop index. All carriers produced high yields. The grade index of tobacco grown with sulfate of ammonia was lowest.

3. An experiment was conducted in which the ratio of organic nitrogen, supplied by cottonseed meal, to inorganic nitrogen, consisting of equal parts from nitrate of soda and ammonium sulfate, varied from 1:7 to 1:1. Good yields and good quality of tobacco were obtained from all treatments, with only insignificant differences in results. A cover crop of oats sown each year may have been an important contributing factor in this experiment.

4. In comparison with the usual method of broadcast application, fertilizer was placed in bands near the plants at the time of setting, by means of special attachments built onto the transplanter. During the first two years of the experiment the results favored row application; but considering the experiment as a whole, broadcast application gave best results. However, the experiment showed that small amounts of fertilizer applied near the plants were proportionately more effective than large amounts broadcast.

From these experiments it was learned in addition: that the amount and distribution of rainfall during the growing season of tobacco are important factors influencing both yield and grade of tobacco; that for best results a comparatively high level of nitrates must be maintained in the soil during the period of most rapid vegetative growth; and that the form of fertilizer nitrogen used bears little or no relation to brown root-rot of tobacco.

The results of these experiments appear to warrant the conclusion that a comparatively high rate of application of fertilizer nitrogen is necessary for growing Havana Seed tobacco of high yield and quality, and that no more than one half and probably as little as one fourth of the nitrogen need come from organic carriers such as cottonseed meal. This recommendation assumes soil and other conditions closely similar to those of these experiments.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 347 MARCH 1938

Annual Report

For the Fiscal Year Ending November 30, 1937

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION -- 1937

INTRODUCTION

F. J. Sievers, Director

The general policy of the Experiment Station Administration is so closely related to and guided by definite research projects that whatever changes occur from year to year are so gradual that they attract very little attention and cause no particular stir. This is as it should be in an organization where there is adequate vision and a sound foundation. Changes which come in the form of sound and gradual growth are generally indicative of a healthy organism. It is the belief that we are undergoing such changes.

One of these, and a very significant one, is evidenced by the increased recognition given to the economic factors that play so prominent a part in the interpretation and utilization of results from scientific investigations. The individual investigator has become gradually more conscious of the desirability and obligation for carrying his studies beyond the so-called factual and into the applied stage. He is developing greater courage in expressing himself in the interpretation of his results and this is sure to prove of great value in a field where unbiased opinions are not readily available from any other source. This development in the Experiment Station is becoming gradually recognized and is being appreciated and encouraged by those whom it attempts to serve.

The work in nutrition, as related to both human and animal well-being, has been hindered since its inception because of inadequate facilities pending the completion of construction in the nutrition laboratory. Last year's appropriation, however, made financial provision to put the entire laboratory into usable condition and this unit will soon be equipped to make a very desirable contribution to the research and general educational program of the entire college. These facilities and the qualified personnel available are being recognized by personal and industrial interests and, as a result, the demands for special research to serve specific problems are increasing.

The investigations under the Mrs. Henry Lang Fund have been encouraged by another gift of $5,000 from the same donor through whose generosity the fund was originally established and designated. There are evidences that this support is beginning to produce results that may aid in providing a more intelligent approach in dealing with those so-called deficiency ailments now so commonly recognized in human nutrition.

Among the poultrymen there is continued interest in the expansion of our facilities so that some of the nutrition problems now confronting that industry may be given research attention. A special item in the present budget, when approved, will provide this service, which should then be organized as a supplement to the present Feed Control program.

Because of opportunities for expansion through enlarged Bankhead-Jones support, it is intended to recognize the need for certain studies in weed control and fruit storage at the Cranberry Field Station. The urgency of this need is best evidenced by the fact that the cranberry growers themselves, through special funds provided through the treasury of the Cape Cod Cranberry Growers'

Association, have attempted to support the preliminary investigations inaugurated in this field. An additional staff member should be provided for that purpose.

The rapid development of interest in enlarged recreational facilities in New England, and especially in Massachusetts, has confronted us with many requests for information regarding the improvement of golf courses, lawns, roadsides, parks, etc. The Massachusetts Greenkeepers' Association has been most active and also most considerate in these demands. Realizing that the expansion of our service is possible only if adequate funds are available, this Association is determined to gain recognition either through an item in our budget or through special legislative action. If adequate financial provision is made available, the research in the Experiment Station can easily be expanded to deal with these problems.

The demands of the Arborists for more specific data regarding the culture of shade trees are gradually being met through certain services made available in conjunction with the activities under Dutch Elm Disease Control. Also, the enlarged facilities provided at the Waltham Field Station as a result of additional greenhouse and laboratory space for Nurseryculture which have just become available through new construction will serve in that connection.

The Regional Pasture Management Laboratory, established at Pennsylvania State College, which is now fully equipped and manned, is intended to supplement the research of the entire northeastern section of this country. It is sure to play a prominent part in promoting a better approach to the evaluation of the management phases involved in providing more satisfactory forage, a matter so essential to the success of the Massachusetts Dairy Industry.

Of the numerous cooperative investigations under way with several bureaus of the United States Department of Agriculture, the most recent, and in some respects the most interesting, is that dealing with soil erosion and its control. Most of New England, due to natural and economic factors, has developed a type of agriculture where pasture and grasslands play such a prominent part that the extreme erosion, quite common in other sections, is rarely in evidence. Nevertheless, the productivity of our soils is recognized as our most important natural resource and therefore deserving of our best consideration because the future prosperity of this country is very closely related to and dependent upon it.

In recent years cooperation in research has been given a great deal of encouragement. To the extent that it remains on a voluntary basis this is very desirable because it has a tendency to overcome some of the limitations of the high degree of specialization that has developed in agricultural research. When cooperation is promoted to the point where it takes on compulsory aspects it not only loses most of its value but may even become a handicap to sound progress. This is especially true when it reaches a stage where conclusions are based upon a compromise of opinions of the cooperative agencies rather than upon the actual research findings of individual investigators. Projects should not be undertaken on a cooperative basis unless it becomes evident, after careful analysis of all factors involved, that such an approach is desirable or even possible.

AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

A study of Pasture Improvement and Soil Management Practices in Massachusetts in Relation to Dairy Farm Organization. (C. R. Creek and D. C. Plastridge.) The results of this project were reported originally on a "type-of-farming area" basis to the cooperating agencies in Washington. In order to make the material more useful to the farmers of the State and to the Extension Service in the various counties, the data from the 113 farm records were retabulated and analyzed on a county basis. Copies of these reports were given to the farmers who cooperated in this project by supplying information on pasture treatment and farm organization. The results were also used by the extension specialists in county meetings on pasture management.

The years in which the seeded pastures were first treated ranged from 1920 to 1936, but the greater number of farmers began an intensive system of pasture treatment after 1929. The following table shows the number of farms and acres of each treatment for initial improvement of seeded pasture.

	Seeded		Fertilized		Limed	
County	Farms	Acres	Farms	Acres	Farms	Acres
Berkshire.......	22	354.3	21	346.3	12	154.8
Franklin.......	10	115.0	10	115.0	6	58.0
Hampshire.....	13	286.0	12	268.0	8	86.0
Hampden......	14	80.8	12	72.8	10	69.5
Worcester......	13	215.5	13	215.5	9	93.5
Essex..........	5	44.5	5	44.5	3	14.0
Middlesex......	7	178.8	7	176.5	4	134.0
Norfolk........	2	29.0	2	29.0	2	29.0
Bristol.........	3	29.1	3	21.7	3	23.4
Plymouth......	4	34.5	4	34.5	2	17.5
Total..........	93	1367.5	89	1323.8	59	679.7

Prepared seeding mixtures for hayland and pasture, as well as miscellaneous mixtures of clovers and grasses, were used in the original improvement practices. In recent years, a greater acreage of Ladino clover has been seeded, especially in Berkshire county. Complete fertilizers, cyanamid, calnitro, and superphosphate were the chief materials used for the fertilizer treatments, with rates varying from 100 to 2000 pounds per acre. Ground limestone was the choice on the majority of farms, although hydrated lime was used in a few instances.

Fertilizers and lime were applied to established stands of hay and pasture grass on 57 farms as the initial pasture improvement practice. A total of 779 acres was fertilized and only 113 acres were limed in this type of treatment. The rate of application per acre varied widely for the different kinds of fertilizers used. Cyanamid, calnitro and high analysis complete fertilizers were seldom applied in excess of 500 pounds per acre.

The results of pasture treatment can be measured in the increased number of cow-days of grazing which are supplied per acre. Open untreated pasture on the farms surveyed furnished from 28 to 107 cow-days of grazing, while the seeded and treated pasture on these farms supplied from 142 to 289 cow-days per acre. Grazing on unseeded treated pasture ranged from 57 to 179 cow-days per acre.

Case studies were made on the effect of pasture improvement on the organization of four dairy farms in the survey. These farms were in Plymouth, Worcester, Hampshire and Berkshire counties and in 1935-36 had milking herds ranging in number from 22 to 27 cows. A comparison was made of the pasture program and farm organization for the year before intensive pasture treatment and for the year 1935-36. The herds increased in size during this period by two, three, eight, and eleven cows. Milk was sold at retail on two farms and wholesale on the other two. Milk production per cow increased in 1935-36 over the former period on two farms and decreased on two. However, the total milk production was greater in the latter year on three farms. Adjustments in the dairy enterprise which were due partially to the pasture program also brought out changes in the organization of other enterprises on the farms.

The pasture program on Farm A consisted of alternating a small acreage of land between hay and pasture use and maintaining high yields with heavy applications of fertilizer and lime. Permanent fertilized pasture was supplemented by grazing from nurse crops and specially seeded annual pasture crops on Farm B. Seeded and treated permanent pasture was used on Farm C, but did not supply grazing for the entire season. Annual and rowen pasture are needed on this farm to supply adequate grazing. Farm D had a system of permanent seeded pasture which was grazed in small plots in rotation. Rowen pasture was used to supplement this treated pasture.

A Study of Adjustments in Dairy Farm Organization and Practices in Massachusetts. (C. R. Creek.) This project was undertaken in May 1937 in cooperation with the Bureau of Agricultural Economics of the United States Department of Agriculture to obtain basic data on farm organization, on physical and financial requirements for production, and on farmers' adjustments to various economic and technical changes. Another objective was to determine the relative profitableness of different farm organizations and of farming in the various dairy areas of the state.

Survey records of the farm business for the year May 1, 1936, to April 30, 1937, were taken on 263 farms in eleven counties during the summer of 1937. These will form a basis for the selection of farms in the dairy farming areas for case studies of organization and management. The schedules for seven counties, which comprise a total of 134 farms, were sent to the Washington office for tabulation. Cards have been prepared for 129 farms in Worcester, Franklin, Hampshire and Hampden counties, and contain physical and financial factors of the farm organization and operation for one year.

Case studies of the organization and management of three farms in the western Middlesex and eastern Worcester county area have been started. These farms have dairy, poultry, and orchard enterprises in their organizations and it is planned to determine the relationship between these enterprises under the three sets of conditions found on the farms.

An Economic Study of Secondary Milk Markets in Massachusetts. Group I—Connecticut Valley. (A. A. Brown, C. R. Creek, and J. E. Donley.) The supply side of the market has been emphasized during the past year. Location of most Massachusetts producers within the milkshed has shown a clustering of dairy farms in groups; a clustering which at present appears to be the result of natural conditions. One of these groups lies to the southwest of the Springfield market in the towns of Southwick and Agawam.

In 1935 the average daily deliveries of most of the producers in the Southwick-Agawam section were from 90 to 120 pounds; the average net price 2.40 per hundredweight. This situation indicates that the difficulties of the dairy farmer are due more to a small volume of sales than to a low price. In fact, with such a small volume of sales, the practical limits to which prices might be raised would offer little relief.

The transportation of milk from farms to city plants is poorly organized and costly to producers. Ninety-four farmers shipped milk to ten different dealers in May 1935, the milk being hauled on ten different trucks. Although none of the producers lived more than 18 miles from his most distant dealer, the trucks traveled 255 miles. Rates for cartage ranged from 20 to 80 cents per hundredweight, with most of the farmers paying 30 to 35 cents. The sole principle applied in most instances in determining rates must have been "charge what the traffic will bear." Milk cartage is essentially monopolistic in this section. As such it might be subject to the authority of the Massachusetts Department of Public Utilities or the Massachusetts Milk Control Board. An equitable and logical rate structure based on distance from market by zones and location would materially increase the efficiency of cartage and remove the cartage rate from the field as a price lever. Without materially affecting existing producer-distributor relationships, routes could be so reorganized as to reduce the mileage traveled by 40 percent and the number of routes to six.

Use of butterfat standards is general throughout the market process. The minimum legal butterfat test in Massachusetts is 3.35 with minimum total solids of 12 percent. In order that milk may test 12 percent solids it must contain a minimum of 3.65 percent butterfat. Dealers' purchases are for the most part on a 3.7 percent basis. Sales are generally on a 4 percent basis. Lack of uniformity in butterfat standards of purchases and sales is most serious. Prices to producers are largely determined on the ratio of purchases to sales irrespective of test. With sales being made at a higher test than purchases, the ratio is inaccurate and discriminating against producers. The situation can be corrected by utilizing milk equivalent volumes of the same standard.

DEPARTMENT OF AGRICULTURAL ENGINEERING

C. I. Gunness in Charge

Cold Storage of Cranberries. (C. I. Gunness, H. J. Franklin, and C. R. Fellers.) A study on the storage of cranberries was started in the fall of 1936. Berries were stored in four typical storages, such as are commonly used by growers, and in addition berries were stored in a refrigerated storage at 30°, 35°, and 50°. The losses in the various storages are shown in Table 1.

TABLE 1.—Storage Losses in Percent, 1936-1937

Storage Conditions	30°	35°	50°	Average of Common Storages
Early Black, picked Sept. 9:				
Stored Sept. 9-Nov. 10.....	3.9	4.7	6.2	11.4
Stored Sept. 9-Nov. 30.....	9.6	4.0	7.7	17.3
Early Black, picked Sept. 25:				
Stored Sept. 25-Nov. 10....	4.5	5.3	9.8	18.2
Stored Sept. 25-Nov. 30....	12.8	10.9	18.4	29.6
Howes, picked Sept. 25:				
Stored Sept. 25-Nov. 30....	2.7	4.3	9.9	13.9
Stored Sept. 25-Jan. 31....	32.6	16.5	26.2	39.5
Howes, picked Oct. 15:				
Stored Oct. 15-Nov. 30.....	4.2	3.8	7.8	10.0
Stored Oct. 15-Jan. 31.....	17.1	17.5	27.6	33.4

The Early Black berries picked on September 9 were quite "green" in appearance and not in prime condition for sale. Those stored at 50° colored very satisfactorily in storage, while those stored at 30° and 35° had changed but little during the storage period. Those held in common storage had colored slightly more than those held at 30° and 35°, but far less than those stored at 50°. This was true in spite of the fact that the temperature in the common storage rooms averaged considerably higher than 50°.

Early Blacks picked on September 25 were well colored, so there was but slight opportunity for further coloring. The berries stored at 50° did, however, show deeper reddish color than any of the other samples.

The observations in regard to coloring of Early Blacks were duplicated on Howes. Those picked "green" colored materially more at 50° than at other temperatures, and the same tendency was noticed on those which were well colored when picked.

An experimental storage was provided for the 1937 crop, with facilities for holding berries at 35°, 40°, 45°, and 50°. Berries were stored at these temperatures, as well as in three common storages. The storage losses are given in Table 2.

TABLE 2.—Storage Losses in Percent, 1937-1938

Storage Conditions	35°	40°	45°	50°	Average of Common Storages
Early Black, picked Sept. 9:					
Stored Sept. 9-Nov. 10	3.8	3.4	3.3	5.5	11.8
Stored Sept. 9-Nov. 30	5.5	5.9	8.0	10.4	18.3
Early Black, picked Sept. 25:					
Stored Sept. 25-Nov. 10	1.4	1.7	3.1	3.9	6.8
Stored Sept. 25-Nov. 30	2.9	4.5	6.3	8.1	11.9
Howes, picked Sept. 25:					
Stored Sept. 25-Nov. 30	3.1	3.3	4.4	5.1	7.2
Stored Sept. 25-Jan. 31	10.6	11.5	12.8	13.3	12.3
Howes, picked Oct 15:					
Stored Oct. 15-Nov. 30	1.9	2.5	3.0	4.3	4.2
Stored Oct. 15-Jan. 31	11.4	12.2	10.2	11.8	10.8

Coloring of the various lots of berries in storage in 1937 was very similar to that in 1936. There was no appreciable difference in coloring in berries stored at 45° and at 50°, but both these lots were more highly colored than any of the other lots. The development of color in storage was naturally most noticeable on berries which were picked "green."

A study of the results obtained would seem to justify the following conclusions:

1. Minimum storage losses will occur if berries are held at 35°.
2. "Green" berries can be colored most satisfactorily at a temperature of 45°.
3. Storage losses can be reduced from 5 to 10 percent by holding berries at from 35° to 45°, as compared with storage in the ordinary screenhouse.
4. The reduction in storage loss through the use of mechanical refrigeration will naturally be greater on berries harvested early than those picked late. Temperatures in the ordinary screenhouse are high in the early part of September but drop appreciably by the first of October.

Apple Storage Investigation. (C. I. Gunness.) The work on apple storages during the past year has been confined to observations on the behavior of refrigeration plants using low pressure gases, such as methyl chloride and Freon, with blowers equipped with copper fin-type coils. Where blowers are of ample size, they have given satisfactory results in defrosting, particularly inasmuch as most farm storages are operated at a temperature a few degrees above freezing during the loading period.

Low-lift Pumps for Cranberry Bogs. (C. I. Gunness.) In the last annual report it was stated that tests had been conducted on a low-lift pump designed particularly to meet the needs of cranberry growers. During the past summer additional tests on this same pump were made at different speeds. The data obtained from these latter tests serve to aid the grower in the selection of speeds to meet his needs as affected by available power and head and capacity requirements.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Tobacco Projects. (Walter S. Eisenmenger and Karol J. Kucinski.)

Cropping Systems. Tobacco grown following other crops is frequently infected with a disease known as brown root-rot. Studies have shown that the chances for serious infection are much less following certain crops than when tobacco follows certain other crops. It would seem, therefore, that the most satisfactory control for the disease on tobacco grown in rotation is to precede tobacco with a crop which will reduce the chances of serious infection to a minimum. Since the last report, the tobacco crop of 1936 has been sorted, and additional information has been obtained as to the quality of the tobacco.

The yield and quality of the tobacco grown on manure was better than that grown with any of the different cover crops. The cover crops used, however, were not injurious to the yield and grade of tobacco. From general observation it was found that tobacco, when it was planted following a 2-year-old hay sod, did better with respect to yield and quality than when it followed a 1-year-old hay sod.

Spacing Experiment. The experiment to determine the comparative effects of different spacing of plants upon the yields and quality of tobacco produced by a larger-growing strain and by a smaller-growing strain of Havana seed tobacco was continued in 1937, according to the plan of experiment used for the purpose in 1936. Planting distances of 36, 39, and 42 inches between rows were used in combination with 12, 15, 18, 21, and 24, and 27 inches between plants. For both years in every combination of planting distances, the larger-growing strain produced a greater yield per acre and the crop index was substantially better. It was found that the quality of the tobacco was perhaps a little better when the plants were planted 24 inches apart in the 36- and 39-inch rows, and 18 inches apart in the 42-inch rows. On the other hand, the crop index, which is the product of both the yield and quality, showed up favorably and nearly equal when the tobacco was planted with 18 inches between plants and 36 inches between rows; 15 inches between plants and 39 inches between rows; and 12 inches between plants and 42 inches between rows. From the data collected, field observations, and practicability of handling of the tobacco in the field, especially with the larger-growing strain, it seems that perhaps the most favorable results could be obtained when the plantings are made with 18 inches between plants and 39 inches between rows. This conclusion is drawn from only 2 years' experimentation.

This experiment should be carried out for a longer period of time before any definite conclusion can be stated.

The Effect of Plants Grown in the Field on the Subsequent Tobacco Planted in Rotation. (Walter S. Eisenmenger and Karol J. Kucinski.) It has been a conjecture of the writers that there was a possible relationship between the botanical species and rate of ammonification and nitrification of plant tissue and the capacity to induce brown root-rot when different plants were grown in rotation with tobacco.

All the grasses tried with the exception of red top are conducive to the occurrence of the trouble. Red top decomposes the most slowly of all the grasses used in rotation.

The *Solanaceae*, potatoes, tomatoes, etc., do not seem to induce the trouble. They decompose exceedingly rapidly to ammonia and nitrate nitrogen. Ragweed and horseweed decompose fairly rapidly, and do not induce the malady.

In 1936, the following varieties of plants were planted in a field, there being 4 plots of each: horseweed, alfalfa, Canada bluegrass, Kentucky bluegrass, sweet clover, orchard grass, red clover, rye, wheat, artichoke, red top, ragweed, gladiolus, turnip, tomato, pepper, cabbage, squash, sudan grass, sorghum, buckwheat, carrots, millet, and seaweed (applied). The relative rate of ammonification and nitrification of these plant tissues is known from previous experiments.

This year tobacco was planted where these plants were grown in 1936. The following table represents the yield and quality of the tobacco grown after these different crops.

Average Yield and Quality of Tobacco

Preceding Crop	Pounds per acre	*Grade Index	*Crop Index
Tobacco	2125	.534	1135
Horseweed	2099	.495	1039
Alfalfa	2049	.499	1022
Canada bluegrass	2093	.510	1067
Kentucky bluegrass	2062	.509	1050
Sweet clover	2089	.524	1095
Orchard grass	2124	.500	1062
Red clover	2051	.494	1013
Rye	2097	.504	1057
Wheat	2187	.506	1107
Artichoke	2044	.510	1042
Red top	2160	.525	1134
Ragweed	2037	.475	968
Gladiolus	2034	.478	972
Turnips	2006	.494	991
Tomatoes	2143	.492	1054
Peppers	2238	.477	1068
Cabbage	2129	.508	1082
Summer squash	2245	.491	1102
Sudan grass	1936	.487	943
Sorghum	1853	.474	878
Buckwheat	2106	.499	1051
Carrots	2127	.496	1055
Seaweed	2643	.443	1171
Millet	2143	.507	1082

*The explanation of grade index and crop index will be found on page 21. The relative values used in 1937 are not identical with those used in previous years but are very similar.

The plants of the grass family were variable in their effect on subsequent tobacco yields, while the legumes and Solanaceae were more consistent. The latter family seem to have the virtue of being conducive to a good yield of tobacco when they precede tobacco.

Distribution of Nitrogen in Soils Mixed with Different Plant Tissues and Allowed to React for Two Months. (Walter S. Eisenmenger.) Tobacco planted in rotation with corn and timothy is frequently subject to brown root-rot, while tobacco following tobacco or certain weeds, as ragweed or horseweed, seems less susceptible to the disease.

It was found that tobacco, ragweed, and horseweed, when placed in the soil, decomposed more rapidly and with a higher rate of nitrification or ammonification than did red top, corn, and timothy. Clover, when placed in the soil, also had a high rate of ammonification and nitrification, but it was similar to timothy and corn in causing the brown root-rot to appear when planted in rotation with tobacco. The intial rate of decomposition, therefore, is not the only indicator of this trouble.

Clover, timothy, corn, and red top are relatively high in lignin, while tobacco, ragweed, and horseweed are relatively low in lignin. Those plants which are high in lignin, or which maintain their physical structure fairly well during winter weather, are the ones which are least desirable for crops in rotation with tobacco.

Application of Calcium Cyanamide to Overcome the Immediate Harmful Effects of Ligneous Tissue. (Walter S. Eisenmenger and Karol J. Kucinski.) Attempts were made to overcome the bad effects which the residual portions of certain preceding crops have on tobacco. Tobacco plants seem exceptionally sensitive to the effects of the slowly decomposing portions of certain crop plants in the soil.

Applications of nitrogen in the form of calcium cyanamide were made in the fall to plots of corn, red top, orchard grass, and timothy. Similar plots which received no nitrogen were used as check plots. The red top, orchard grass, and timothy plots were two-year-old sods of the respective grasses. Immediately after the nitrogen was applied, all of the plots, including the checks, were plowed under and seeded to a cover crop of rye. The following spring, tobacco was planted on all of these plots.

Plot Treatment	Yield and Quality of Tobacco		
	Acre Yield Pounds	Grade Index	Crop Index
Cornfield			
Plowed — Check	1837	.489	898
500 lb. per acre of calcium cyanamide added before plowing	2169	.555	1203
Two-Year-Old Red Top Sod			
Plowed — Check	1782	.508	905
500 lb. per acre of calcium cyanamide added before plowing	2432	.538	1308
Two-Year-Old Orchard Grass Sod			
Plowed — Check	1935	.524	1014
500 lb. per acre of calcium cyanamide added before plowing	1877	.499	937
Two-Year-Old Timothy Sod			
Plowed — Check	1793	.536	961
500 lb. per acre of calcium cyanamide added before plowing	2185	.508	1110

With the exception of the orchard grass plots, the table above shows that the yields of tobacco and their respective crop indexes were materially increased by the additions of nitrogen before plowing under the preceding crop.

The Use of Nitrogen as an Aid in Decomposing Old Sod. (John M. Zak, Karol J. Kucinski, and Walter S. Eisenmenger.) It is of interest to find out whether the application of nitrogen to old grass sod before it is plowed under will hasten decomposition and thus counteract the bad effects usually experienced when crops are grown on newly plowed old sod. Applications of calcium cyanamide at the rates of 100 and 50 pounds of nitrogen per acre on old sod before plowing in the early spring proved to be effective in hastening decomposition. The yields obtained on the treated area were higher than those obtained on the check area of sod which received no nitrogen before being plowed. Another area that received the same treatment but was plowed late in the spring showed similar results but to a lesser extent. Determination of ammonia and nitrate nitrogen throughout the growing season showed that the rate of decomposition of the old sod was faster where nitrogen was plowed under. Study of the yields and the chemical analyses shows that the addition of nitrogen to old sods before plowing them under will greatly aid in their decomposition and thus lessen their usually harmful effects.

Rate of Decomposition of Materials Used as Bedding for Animals. (Walter S. Eisenmenger and John M. Zak.) The following bedding materials were analyzed for total nitrogen: southern pine sawdust, southern pine shavings, white pine sawdust, cedar sawdust, hemlock shavings, chestnut sawdust, oak sawdust, birch shavings, peanut hulls, and cacao hulls. A mixture of one half bedding material and one half soil (on a dry-weight basis) was placed in individual crocks and sufficient nitrogen added to each to bring it up to one percent. Determinations are being made of the rate of ammonification, nitrification, and decomposition of lignin.

In another series, cow urine was added to each bedding to the point of saturation, and the material allowed to decompose. Lignin and nitrogen determinations are being made at the beginning and end of the process to study the comparative changes in the various materials.

Magnesium Requirements of Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) Parts of a field known to be deficient in magnesium were used in 1936 to determine the relative response and tolerance of different crops to deficiencies of this element. A mixed fertilizer, containing no calcium and no magnesium was applied to the entire field, and magnesium sulfate and ground limestone were added as shown in the table. Chemical analyses were made of representative samples of crops grown on these plots. The results of analyses of mangels, potatoes, and rutabagas would indicate definitely that wherever magnesium is applied the amount in the plants is increased. Where calcium is applied, not in all instances is the amount increased in the plant.

Plot	Treatment	Analysis on Dry-Matter Basis, Percent					
		Mangels		Potatoes		Rutabagas	
		CaO	MgO	CaO	MgO	CaO	MgO
A	Check	.555	.135	.057	.151	.689	.181
B	Magnesium	.278	.221	.047	.179	.770	.268
C	Magnesium and lime	.364	.201	.065	.194	.819	.228
D	Lime	.637	.157	.066	.147	.698	.173

Different crops were grown on the same plots in 1937 with similar fertilizer treatment. On the basis of field observation alone, the apparent relative tolerance of these crops to the magnesium deficiency, obtained under these conditions, is as follows:

Tolerant

- Alfalfa
- Beans
- Beets (red)
- Hollyhock
- Millet
- Peas
- Rape
- Rye
- Soybean
- Sudan Grass
- Sunflower
- Sweet Potatoes
- Swiss Chard

Not Tolerant

- *Abutilon avicennoe* (velvet leaf)
- Buckwheat
- Cabbage
- Corn
- Cucumber
- Mangels
- Muskmelon
- Pepper
- Potatoes
- Pumpkin
- Rutabagas
- Tobacco
- Tomato
- Watermelon

It was also observed that the areas (C and D) which had been continuously limed showed symptoms of detrimental effects. Pronounced signs of frenching of tobacco were witnessed on these two areas, while turnips and rutabagas were a failure even though there was considerable growth of tops.

Soil Treatment for Potatoes. (Walter S. Eisenmenger and Karol J. Kucinski.) The purpose of this experiment was to determine the value of calcium in the form of different compounds, a slight difference in pH, the degree of stimulation due to unusual ions, and the effects of large amounts of organic matter.

A plot of soil was divided into two parts. To one half was applied gypsum at the rate of one ton per acre; to the other half was applied an equivalent amount of calcium in the form of ground limestone. Sweet clover was planted on both parts of the plot and plowed under when in full bloom. Each half was subdivided into smaller plots, and these were treated with various chemicals previous to planting of the potatoes. The following are the comparative yields.

	Average Yield per Acre Bushels	
Treatment	Gypsum	Limestone
Lead sulfate	387	378
Boron	408	393
Zinc sulfate	393	405
Manganese sulfate	399	390
Magnesium sulfate	393	387
Check, with treated seed pieces	372	390
Check, no chemicals	360	396
Mercuric chloride	372	366
"Dubay"	357	384
Cadmium chloride	396	396

A check plot on which no lime or sweet clover cover was used produced 359 bushels per acre.

The results would indicate that the extremely desirable effects of boron, lead, zinc, cadmium, and magnesium are not in evidence. No evidence is at hand as to scab prevention, as scab was not prevalent in any case. In all cases the organic matter improved the yield.

Onion Breeding. (W. G. Colby and Hrant M. Yegian.) The work in onion breeding this past season consisted mainly of combining closely related lines either in open pollinated isolation blocks or under cages with the aid of flies. Seed of some 25 strains, including strains of both late seed and Ebenezer set types, were obtained in this manner. These strains, some of which show promise, will be compared with commercial strains to determine whether or not the breeding work of the past two years has really produced any strains of a superior character.

Some new breeding work was initiated with seed onions. Some 1200 selected bulbs of a late seed strain and 300 selected bulbs of an early seed strain were selfed. This material will serve as foundation stock for a new breeding program for each of these two types of seed onion.

Pasture Experiments. (W. G. Colby.) The schedule of mineral fertilizer applications was maintained on plots in six permanent pastures in Worcester County. In addition to the regular mineral top-dressing treatment, one plot in each of four of the pastures received a heavy top-dressing of manure over one half and a heavy application of a complete fertilizer over the other half. In the center of each half, a small area (2′ x 3′) was spaded to a depth of six inches. The whole experimental area, including the spaded plots, was then seeded with a mixture of wild white clover and Ladino clover at the rate of three pounds to the acre. A cage was placed over the spaded areas to prevent grazing of the young clover seedlings.

The response to the top-dressing applications of mineral fertilizer was evident but was no more pronounced than in previous years. The response to manure as a top-dressing appeared to be greater than the response to mineral fertilizers, but in no case was the difference great. In the small area which was spaded, on the other hand, a dense growth of clover was obtained on both the "complete fertilizer" side and on the "manure" side of the plot. In fact, the clover seeding caught in only those small areas which were spaded. Elsewhere over the experimental area, only a few weak plants resulted from the seeding operation. From these trials, it is obvious that the physical condition of the soil in permanent pastures, as well as the supply of available plant food elements, is an important factor in influencing the growth of pasture herbage.

Breeding Perennial Pasture Plants. (W. G. Colby and Hrant M. Yegian.) Breeding work with perennial pasture plants is for the most part still in the inventory stage. Studies are being carried on to determine the range of hereditary variation that exists in our native pasture legumes and grasses, and studies are also being made of the environmental adaptability as well as the range of hereditary variation of foreign strains of pasture plants.

Some actual breeding work was begun with Ladino clover by planting a nursery of 2,500 spaced plants, grown from seed. The selection of a Ladino clover strain, possessing greater winter hardiness, is the principal object of this experiment.

Effect of Fertilizer Ratios on Mowings. (Karol J. Kucinski and Walter S. Eisenmenger.) This experiment is a continuation of one reported previously. It seemed desirable to find out whether the quality and yield of the forage can be improved and the life of the mowing prolonged by the use of fertilizers. A mixed fertilizer with a varying ratio of nitrogen, phosphoric acid, and potash, was used. Comparisons have been made by maintaining two of the nutrients at a constant level and varying the third. Data accumulated for several years have shown a distinct response to increments of nitrogen and potash. Little or no benefit was derived from applied superphosphate.

The rainfall being plentiful last spring, the response to nitrogen and potash was in line with those of previous years. In the case of phosphoric acid, greater yields were obtained only when the higher level of phosphorus was used.

Proportion of Mixtures Used in Seeding for Hay. (Ralph W. Donaldson, Karol J. Kucinski and Walter S. Eisenmenger.) Trials of thirteen different hay seeding mixtures are being maintained, from which yield data for the first two seasons have been obtained. The mixtures include alfalfa, red clover, timothy, orchard grass, and red top, used in varying combinations to make 21-pound mixtures, ranging from one with no alfalfa up to one with only alfalfa. The thirteen different mixtures are replicated three times at the 21-pound rate, and twice each at 17- and 13-pound rates of seeding per acre. Two cuttings each of the two seasons have been harvested on an area 5 x 90 feet from each of the 99 plots, and recorded as air-dry yields per acre.

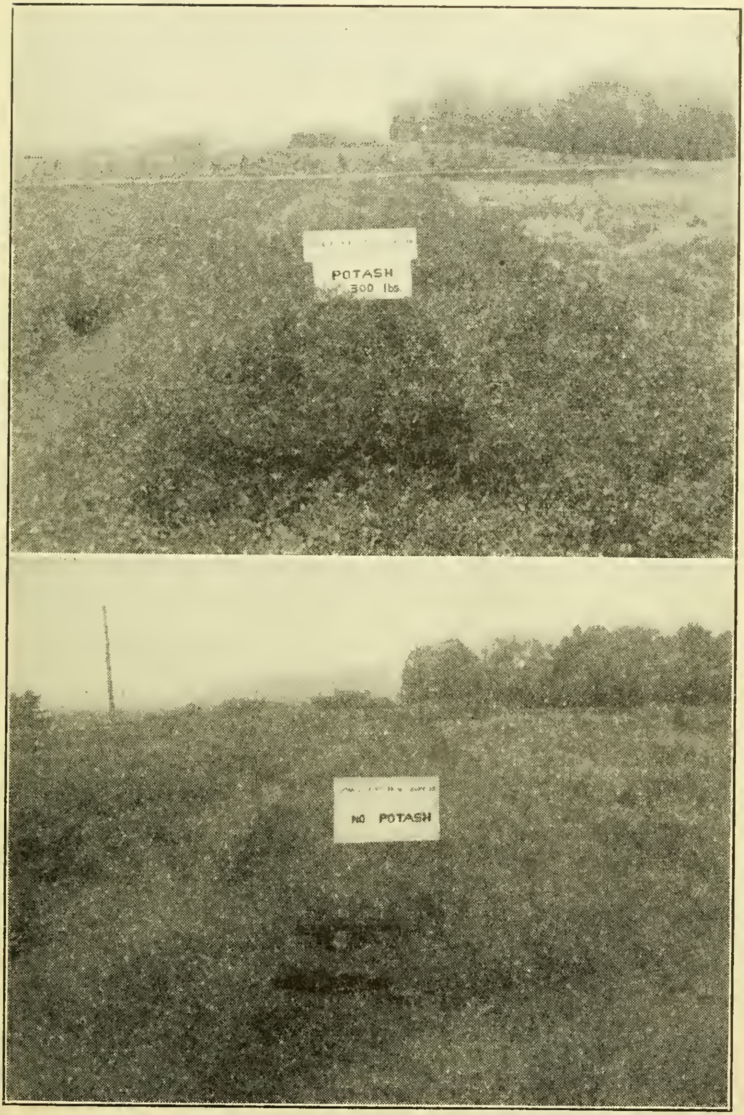
Results show a consistently lower yield for each of the two seasons from all the thirteen mixtures seeded at the 13-pound rate, which averaged 8060 pounds of hay compared with 8981 pounds harvested from the 21-pound rate of seeding—a difference of nearly one-half ton per acre. The 17-pound and the 21-pound rate of seeding showed no consistent difference, although the average yields favored slightly the 21-pound rate.

The differences in yield among the thirteen seed mixtures indicate an advantage from mixtures consisting of one-third to two-thirds alfalfa, along with timothy, clover, and possibly small amounts of red top. Consistently, the two lowest-producing mixtures have been the extremes, no alfalfa and only alfalfa, which have yielded three-fourths of a ton less hay than several other mixtures. Orchard grass, while comparing favorably with timothy in point of yield, appears far less desirable for use in these mixtures, owing to its earlier maturity and some tendency to dominate the stands.

The Effect of Time of Cutting on Yields of Alfalfa and the Use of Potash in Preventing Winterkilling of Alfalfa. (Karol J. Kucinski, Walter S. Eisenmenger and Ralph W. Donaldson.) Mowings of 2-year-old alfalfa were made at definitely spaced intervals of time to determine the best management practices for alfalfa growing. Eight plots were cut three times, and four plots were cut twice per season, beginning in early June and extending to late September. This year, as in 1936, the higher yields of alfalfa were associated with those plots having a schedule of three cuttings. The highest yield was obtained when the first cuttings were made on June 7, the next on August 2, and the last on September 3. In the schedules with two cuttings, the total yields were not as great as any of the total yields from schedules with three cuttings, but the stand of alfalfa in the fall where two cuttings were made was superior to that where three cuttings were made.

In the early summer of 1936, an application of 300 pounds of muriate of potash was made to a portion of each plot, while the other portion received none. In each schedule of cuttings, where the three dates of mowing were relatively close together or where the last mowing was very late in the season, there was a definite winterkilling of the alfalfa plants on that portion of the plot which had not received the application of muriate of potash. The accompanying photograph taken from one of the plots shows that the portion of the plot which received an application of potash withstood the elements of weather and produced a thick stand of fine alfalfa, while on the part not receiving any potash the alfalfa was entirely winterkilled and has been replaced by weeds.

Alfalfa Variety Tests. (Walter S. Eisenmenger and Karol J. Kucinski.) In cooperation with the United States Department of Agriculture, tests are being conducted with fifteen varieties of alfalfa. The comparatively heavy rainfall during the past summer resulted in larger yields for this year than for 1936, except in a few cases. Hardigan and Ontario variegated varieties gave excellent yields in 1936 and were again outstanding in 1937. Varieties from southern states and countries are not adapted to conditions in Amherst.


POTASH
300 lbs.
NO POTASH

The Effect of Potash on the Winterkilling of Alfalfa.

Testing Varieties of Corn for Grain and Silage. (W. G. Colby and Ralph W. Donaldson.) A test of corn varieties begun in 1935 was continued in 1937. Yield data of stover and shelled grain as well as information on time of maturity and habit of growth were obtained on 125 corn varieties. These included Flint and Dent varieties of local and regional importance and also a large number of the best "hybrid" strains from the chief corn-producing sections of the country.

For use in the Connecticut Valley, the varieties tested can be divided into three general groups: early grain, late grain and silage, and silage varieties. The local Flint and Dent varieties together with varieties grown for grain in New York, Michigan, Wisconsin, and Minnesota comprise the early grain group. The grain varieties from Iowa, Illinois, Indiana, Ohio, Pennsylvania, and New Jersey fall into the next or late grain and silage group. The third group is made up of those very late-maturing varieties mostly from the Southern States which mature little if any grain and can be considered only for use as silage.

The best yields of grain and stover can be expected from the late grain and silage varieties. In years of favorable growth and when the date of the first fall freeze is average or later than average, most of these varieties will mature grain in Amherst. However, if the season's growing conditions are unfavorable for corn, these varieties will not mature before frost and can only be used for silage.

If a reliable grain-producing variety is wanted, an early-maturing strain must be selected, which, although not yielding as will later-maturing strains, can be depended upon to consistently reach maturity before the first fall freeze.

Potato Variety Tests. (Ralph W. Donaldson, Walter S. Eisenmenger and Karol J. Kucinski.) Yield tests of ten potato varieties were continued this year on the experiment station farm. Each plot received six applications of Bordeaux mixture, 5-5-50. One series of plots received gypsum ($CaSO_4$) at the rate of one ton per acre, and the other series received the equivalent amount of calcium in the form of ground limestone ($CaCO_3$). Following are the yields per acre in bushels.

Variety	Gypsum Treatment	Limestone Treatment	Average
Green Mountain	382	407	395
Chippewa	384	322	353
Russet Rural	378	301	339
Warba	287	251	269
Katahdin	257	271	264
Houma	261	—	261
Irish Cobbler	284	216	250
Bliss Triumph	235	263	249
Golden	212	201	207
"Idaho Baker"	189	202	195

The Comparative Nutritive Effects of Copper, Zinc, Chromium, and Molybdenum. (H. Robert DeRose, Walter S. Eisenmenger, and Walter S. Ritchie.) Tomatoes, buckwheat, and barley were again grown in crocks in pure white sand which had been washed with aqua regia and then water and heated to 100° C. Knop's solution was used, and the crocks were so regulated as to drain at the rate of 1 liter in 24 hours. All salts used were recrystallized, and distilled water was redistilled from Pyrex glass. Copper was used at the rate of 0, .05, .15, .50, 1.0, and 5.0 parts per million; and zinc at the rate of 0, .05, .15, .50, 1.0, 10.0, and 20.0 p.p.m.

Again it was clearly shown that both copper and zinc had a stimulating effect on tomato plants when used in .05 and .15 p.p.m. concentrations. This was indicated by the height and total dry matter of the plants. In the case of buckwheat, the lower concentrations of copper and zinc indicated slight stimulation.

The tomatoes which were treated with molybdenum in concentrations of 0, 1.0, 5.0, 10.0, 20, 40, and 80 p.p.m., indicated that any concentration above 1 p.p.m. was toxic to the plants. One part per million gave a little better growth than the control, while the plants receiving the higher concentrations were badly stunted. The plants which received amounts of molybdenum greater than 1 p.p.m. in all cases had petioles which were devoid of leaflets for several weeks. Concentrations of 1 p.p.m. and 5.0 p.p.m. of molybdenum had a decided stimulating effect on buckwheat, while concentrations greater than 5 p.p.m. showed toxicity. When barley was thus treated with molybdenum in the same concentrations as tomatoes, it was definitely indicated that 20 p.p.m. and 40 p.p.m. gave the better growth as judged from the height and general vigor of the plants, as well as the total dry weight.

From preliminary results with chromium in concentrations of 0, .50, 1.0, 10, 20, 40, and 80 p.p.m., all of the tomato plants receiving the element showed signs of toxicity.

The chemical analyses of the leaves, roots, and stalks or stems of the various plants are now in process.

Borax Trials on a Market Garden Soil. (Ralph W. Donaldson and Robert E. Young.) A 30-pound rate of borax, applied broadcast prior to planting on Gloucester soil of pH 6.4, eliminated stem crack of celery, resulting in excellent yield and grade, compared with severe cracking and poor growth on no-borax plots. Side applications of borax at the same rate, applied September 2 on untreated rows where crack symptoms first appeared August 20, effected recovery and subsequently produced celery of similar yield and grade.

Crops grown in these trials, conducted by John Handy, County Agent, Concord, Massachusetts, included Golden Plume and Pascal celery, spinach, beans, beets, cauliflower, and rutabagas. Aside from celery, the only crop showing response to borax was rutabagas in which dark center, present on the check plots, was absent on the borax plots initially treated.

Borax Trials. (Ralph W. Donaldson, W. G. Colby, and Walter S. Eisenmenger.) Effects of borax applications, made May 20, at 15-, 30-, 60-, and 120-pound rates per acre broadcast on Plymouth Sand soil type of pH 4.6, were observed on the following crops seeded June 7: beans, beets, corn, carrots, radish, and rutabagas. In addition to a uniform treatment of fertilizer, portions of all plots received limestone at 1000- and 3000-pound rates.

Germination was not noticeably injured on any crops on the 15- and 30-pound rates. Beans were entirely killed on higher rates, but the other crops showed but little injury on the 60-pound rate, and some plants of each crop survived on the 120- pound rate, radishes being most severely injured and rutabagas the least.

Owing to development of weeds, final yield data were abandoned, but late observation showed that best growth of all crops except beans occurred on the 60-pound rate, with boron-deficient turnips appearing only on the check plots.

Field trials in the Connecticut Valley, with borax alone and in a mixture comprising other minor elements applied to onion crops, indicated no control for onion blast.

Weedicidal Properties of Calcium Cyanamide. (Hrant M. Yegian and Lawrence S. Dickinson.) Studies are being made of the weedicidal properties of calcium cyanamide when used in soils previous to sowing seeds of turf grasses and its effect on surface weed seeds in established lawns.

The effectiveness of the chemical appears to be distinctly correlated with the soil moisture, best results being obtained with low rates of application in wet soils. Control is not perfect, but germination of the few surviving weed seeds seems to be sufficiently retarded to permit grass seed, sown eight days after treatment, to make well-established turf.

In established lawns heavily infested with crab grass seed, enough of the seeds were killed to warrant further studies of rate and technique of application.

Increasing the Iron Content of Hay Grown on Soils Producing Nutritional Anemia in Massachusetts Livestock. (Karol J. Kucinski, John G. Archibald and Walter S. Eisenmenger.) During the winter of 1933-34 a peculiar disease of cattle called "neck ail," which had given considerable trouble for a good many years to Massachusetts farmers living around Buzzards Bay and vicinity, was first brought to the attention of the Agricultural Experiment Station.

After a careful investigation, the ailment was diagnosed as a "nutritional anemia." If affected animals were treated with a "drench" of ferric ammonium citrate, recovery to a healthy condition was soon noted. From preliminary work, it was found that both the soil and the grass grown upon it were exceedingly low in iron. It appears, therefore, that the malady is due to the lack of available iron in the sandy soils of this affected region which makes the iron content of the forage very low.

Typical soils of the affected region, known to have produced nutritional anemia in cattle, were brought into the greenhouse, and known amounts of iron salts added to them. Mixed hay grasses were grown on them and analyzed for iron content. They showed an increase of 21.8 to 64.9 percent over the amount of iron found in the controls. The increase of available iron (5 percent oxalic acid extract) in these same soils after treatment ranged from 27.4 to 651.5 percent over the controls.

The Absorption by Food Plants of Chemical Elements Important in Human Nutrition. (Walter S. Eisenmenger and Karol J. Kucinski.) Lettuce and cabbage were grown on soil to which the following cations were added at the rate of 500 parts per million per individual plot; sodium, potassium, magnesium, and calcium. The anions, chlorine, bromine, iodine, sulfate and phosphate, were used on additional plots at the rate of 200 parts per million.

An endeavor is being made to ascertain whether or not those elements found in relatively large amounts in sea water are taken up by the plant in greater quantities than those present in relatively low amounts in sea water.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in Cooperation with the Massachusetts Agricultural Experiment Station

C. V. Kightlinger, U. S. D. A., In Charge

Black Root-Rot. (C. V. Kightlinger.) The purpose of this project is to find strains of Havana Seed tobacco which may be acceptable under Connecticut Valley conditions for resistance to black root-rot and for type of plant, type and quality of leaf, gross yielding capacity and other properties that may be necessary to make the strains acceptable to tobacco growers and cigar manufacturers. It was proposed to accomplish this by a fourfold plan or such portion of the plan as might be necessary; viz., (1) To breed and test numerous strains of Havana

Seed comparatively by means of well-arranged, small plot experimental tests and to select the most promising strains for further and more extensive testing; (2) to conduct the more extensive tests cooperatively with successful tobacco farmers and with cigar manufacturers, to learn the merits of the strains in practical production and commercial uses, and to obtain the criticisms of these men and also their suggestions for the improvement of the strains from their point of view; (3) to improve the strains, if possible, by further selection and breeding, to correct the faults which were detected in the previous cooperative tests; (4) to conduct further cooperative tests with successful tobacco farmers and with cigar manufacturers to obtain, if possible, their approval of the strains.

The results of the first phase of the work were promising. They have been given in previous reports. The complete results of the second phase of the work have not been learned, but the portion of these results that are known are also promising. They have shown the strains to possess merit, but to need improvement in certain respects in order to be entirely acceptable from the point of view of the cigar manufacturers. As a result, the project is now in its third phase of the proposed procedure.

Reductions in Yield and Quality of Tobacco Caused by Mosaic. (C. V. Kightlinger.) Experiments were begun in 1936 to make comparative determinations of reductions in yield and quality of Havana Seed tobacco caused by common tobacco mosaic whose periods of infection were inoculated for at successive 15-day intervals, extending from as soon after time of setting to as near topping time as conditions would permit. Uniform conditions of culture, harvesting, and curing of the tobacco were employed.

The tobacco for these experiments was set June 5 and was harvested August 23. Topping was done August 5. The inoculations for mosaic were made artificially by rubbing the leaves of the plant to be inoculated with expressed juice of mosaic diseased tobacco plants. The dates of inoculation were June 10, June 25, July 10, and July 25. Two replications of the experiment were made.

The average experimental results obtained in 1936 are as follows:

Dates of Inoculation	Average Yield per acre (pounds)	Average Grade Index	Average Crop Index
Control 1	1991	.395	786
June 10	1545	.322	497
June 25	1624	.336	546
Control 2	2006	.393	788
July 10	1709	.348	594
July 25	1840	.372	684
Control 3	2035	.402	818

Grade index, as used here, is a number expressing the grading quality of tobacco produced under the conditions of the experiment. It is based upon the percentage yield of each grade of tobacco and the relative values of these grades given below:

Lights	1.00	Long darks (19″ and longer)	.30
Mediums	.60	Dark stemming (17″ and shorter)	.20
Long seconds (19″ and longer)	.60	Brokes	.10
Short seconds (17″ and shorter)	.30	Fillers	.10

The grade index is derived by multiplying the percentage of each grade of tobacco by the respective rating of the grades, given above, and adding the products.

Crop index, as used here, is a number expressing the crop value of tobacco produced under the conditions of experiment. It is based upon the gross yields of tobacco in pounds per acre and the grade index of the tobacco. Crop index is derived by multiplying the gross yield of tobacco in pounds per acre by the grade index of the tobacco.

Grade index and crop index and the adopted relative values of the different grades of tobacco, as used here, do not necessarily represent current commercial prices of tobacco.

With respect to the average experimental results given above for the several items of data, it should be stated that the respective results for the two replications of the experiment were very similar, with only small differences existing between corresponding items of data.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

The Effect of Feeding a Vitamin A Concentrate on Reproduction in Cattle. (J. G. Archibald, V. A. Rice, and C. H. Parsons.) This project was brought to completion during the year. A preliminary report of results was given at the annual meeting of the Eastern Section, American Dairy Science Association in September. Conclusions drawn at that time are as follows:

Taken individually none of the differences between the groups are significant. However, the evidence as a whole shows a slight trend in favor of the group which received the vitamin A concentrate. Twenty comparisons of various phases of reproductive function are available for the duration of the experiment. Of these, eleven favor the group receiving vitamin A concentrate, six favor the other group, and three are evenly divided.

The effect of the supplement is reflected principally in the birth weight of the calves dropped during the experiment and in a much smaller percentage of stillborn calves.

Since these cattle probably were on better than average rations, it is conceivable that the vitamin supplement might show a more positive effect in some herds, especially where silage is not fed and the hay is of poor quality. The indiscriminate feeding of such supplements regardless of conditions should not be practiced. The individual farmer should study his own particular conditions and decide for himself whether grain mixtures containing vitamin A concentrates are worth the additional cost, bearing in mind always that if for winter feeding he has plenty of early-cut, properly cured hay and well-made corn silage that has not been frosted, and if he has good pasturage in the summer, he will not need to supply additional vitamin A to his cattle.

The Effect of Complex Mineral and Vitamin Mixtures on Milk Production, General Health, and Reproductive Efficiency in Dairy Cattle. (J. G. Archibald.) This project has been continued throughout the year in accordance with the plan outlined in last year's report. Regular quarterly visits have been made to each of the three herds in order to grade the cattle for general appearance and condition, and to exercise proper supervision over the work and the keeping of records. The feeding trials will be terminated during the coming year and the records will then be studied in detail.

A Study of the Mineral Elements of Cows' Milk. (J. G. Archibald, V. A. Rice, and C. H. Parsons.) Supplemental calcium in the form of ground limestone fed to a group of eight cows in the college herd during the winter of 1936-37 did not increase the calcium content of their milk. On the contrary the average calcium content of monthly samples of milk taken in each month from November, 1936, through April, 1937, was slightly lower when the cows received the supplemental calcium than when they were on the standard ration, although the difference was so slight that it was not statistically significant.

This season the effect of supplemental phosphorus on the amount of that element in the milk is being followed in a manner similar to that outlined for calcium in last year's report.

The Effect of Artificial Light on Milk Production. (J. G. Archibald, V. A. Rice, and C. H. Parsons.) This project was seriously interfered with during the latter half of the winter of 1936-37, by the repeated burning out of the special 1000-watt lamps installed for the purpose. The trouble was finally located by the manufacturers of the lights and they are hopeful that the defect has been remedied. Due to partial destruction by fire in September of the building in which the stalls and equipment were located, there has not been an opportunity as yet to test out the improved lights. It is hoped that sufficient repairs will be made before the end of the calendar year to allow the work to proceed.

The small amount of data available shows approximately one percent greater milk production during the 30-day periods when the cows were exposed to the strong light than when they were kept under ordinary conditions as regards lighting. The results need further confirmation before any significance can be attributed to this small increase.

Studies in the Chemistry of Pasture Grass. (J. G. Archibald.) Chemical studies of the grasses grown on the series of plots established in 1930 have been brought to completion with the analysis of the samples obtained in 1936, but the final interpretation of results has not yet been made.

This series of plots was used for palatability tests with cows during the early summer of 1937. The plots were enclosed with a temporary wire fence, and two Jersey cows were turned into the enclosure from about 8:30 a. m. until about 12 noon on each of two successive days at three different times during May and June. The time interval between grazings was determined by the growth of the grass and averaged about 17 days.

A reliable attendant was stationed to watch closely the movements of the cows and to record the time when they started to graze on any given plot and when they left it for another one; also to record any time when they were not grazing. A complete record of each cow's grazing activity and preferences was thus obtained, approximately seven hundred individual observations being recorded. It was planned originally to make further tests in the fall but the growth on the plots did not warrant it. The work will be repeated next year and extended to the second series of plots established in 1934.

While final conclusions cannot be drawn at this time, it is of interest to note that our judgment of the nutritive value of the several species of grasses based on their chemical composition as determined by actual analyses of a large number of samples, is confirmed by the preference shown by these cows. Invariably the cows grazed much more heavily those species having a relatively high content of moisture, protein, and soluble ash, and a relatively low content of crude fiber; they showed scant liking for species relatively high in fiber and relatively low in moisture, protein, and soluble ash; they refused almost entirely one species which has been characterized by a high fiber content over a period of years.

Chemical studies of grasses from the second series of plots referred to above, which was established in 1934 on a very different soil type from the 1930 series, have been continued this year, but at date of writing the analytical work has not been completed.

The Vitamin Content of Certain Pasture Grasses. (W. S. Ritchie and J. G. Archibald. Cooperative with Chemistry.) The laboratory and field work on this project has been completed. (See report of Chemistry Department for details.)

Nutritional Anemia in Cattle in Southeastern Massachusetts. (J. G. Archibald and K. J. Kucinski.) This work has been done in cooperation with the Agronomy Department and with representatives of the Wirthmore feed organization. A paper on the subject, bearing the title appearing above, has been accepted for publication in the *Journal of Dairy Science* but has not yet appeared in print. A summary of the study follows:

A disease of cattle locally known as "neck ail," of long standing in certain localities of southeastern Massachusetts, has been shown to be identical with nutritional anemia of cattle occurring in various widely scattered portions of the world and known by various names. The disease is characterized by emaciation, loss of appetite, and a diminution in the red blood cells and in the hemoglobin content of the blood of affected animals. It is caused by an insufficient amount of iron in the native forage which in turn is due to a very low content of iron in the soils on which the forage is grown. As with cases reported by other investigators, spectacular recovery has followed the administration of iron compounds to the affected animals.

Addition of an iron compound (iron ammonium citrate) to soils from farms where the disease had occurred, resulted in a uniform large increase in the percentage of iron in grasses grown on these soils. This suggests an alternative method for prevention of the disease.

Investigation of the Merits of Molasses-Grass Silage for our Particular Conditions. (J. G. Archibald and C. H. Parsons.) Preliminary work was done on this problem last year. Funds were not available for the erection of a permanent silo, so a temporary silo made from snow fence and building paper was erected in which 35 tons of green grass were preserved with approximately 2300 pounds of molasses. This arrangement proved only partially satisfactory. Due perhaps to inexperience in erecting the temporary silo there was much more waste than is ordinarily the case in the preservation of crops by ensiling. The limited feeding trials possible with the amount of silage available indicated that it was at least as good as dry hay for milk production.

During the present year funds were obtained for the dismantling of a 100-ton silo at the Brooks farm barn no longer in use there, and its re-erection on a concrete base at the main dairy barn. When re-erected the structure was insulated with a special felt base heavy building paper and the whole reinforced with a spiral casing of redwood veneer. This makes a very satisfactory permanent triple-wall silo, for all practical purposes the equivalent of a new structure, at a somewhat smaller cost. In June of this year there were stored in this silo 114 tons of chopped grass mixed with 4 tons of molasses, much of the work being done under weather conditions which made ordinary haymaking impossible. An extensive feeding trial comparing the grass silage with corn silage and also with dry hay for milk production is now in progress and will be continued until the end of the barn feeding season the latter part of April.

Daughters' Records Alone versus Daughter–Dam Comparisons in Predicting Transmitting Abilities of Dairy Bulls. (V. A. Rice.) A previous study of records in the Guernsey breed had indicated that when pedigrees of bulls could be made complete for two generations by including indexes of the bulls therein and records on the cows, the transmitting abilities of these bulls for milk production and percentage of fat could be fairly accurately ascertained. In the previous work the dams' and granddams' records were averaged with their respective sire's indexes and this figure used as the transmitting ability or index of the cows. The index of the immediate sire was averaged with the transmitting index of the dam and .6 of this amount added to .4 of the average of the indexes of the two grandsires and the transmitting indexes of the two granddams. This sum is called the Prediction or Pedigree index. It is built on indexes which are the result of comparing daughters' production with that of their dams.

Some investigators have claimed that the daughters' records alone are a better measure of the transmitting ability of their sire than is an index. This seems questionable since both sire and dam supposedly contribute about equally to their offsprings' capabilities.

The Jersey breed publishes a tested sire list which gives the average production of the daughters of all bulls with ten or more daughters with records. A study was made of this material to try to determine its prediction value for bulls of the Jersey breed. Thirty-five bulls (the same number as used in the previous Guernsey study) whose pedigree could be made complete for two generations were chosen at random. The sires and grandsires of these bulls were in the tested sire list and the average production of their daughters known. The dams had records and the granddams also had records and their sires were in the tested sire list. The material was used as indicated above to obtain the Prediction or Pedigree index. The records as published in the tested sire list are not corrected to a standard number of milkings per day. The daughters of one bull might have made their records on four-times-a-day milking and those of another bull on twice-a-day milking. This is obviously unfair, so the material was used both in its original printed form and also corrected to a standard three-times-a-day milking.

On the uncorrected basis the composite pedigree index of these thirty-five bulls was 11,684 pounds of milk testing 5.41 percent fat. This is what the daughters of these bulls should have produced if the method is sound genetically and the records complete enough. They actually averaged 10,684 pounds of milk testing 5.37 percent. This is a 10 percent error. The individual errors ranged from −52 to +18 percent. When corrected to standard three-times-a-day milking, the daughters were expected to produce 12,232 pounds of milk testing 5.41 percent fat. They actually produced 11,409 pounds of milk testing 5.37 percent fat; an 8 percent discrepancy with the individual errors ranging from −41 to +13 percent.

In the Guernsey breed, using indexes instead of daughters' records only, the error on the composite thirty-five bulls had been 0.7 percent and the range of individual errors −16 to +14 percent.

The writer then tried various combinations of parts of these Jersey Pedigrees in an effort to find a practical way of using this material to predict what the daughters of a young bull would produce. The results are indicated in the accompanying table.

The task of the breeder is to ascertain, beforehand if possible, the potentialities contained in the germ cells, particularly of breeding bulls. Only in this way does it seem possible to take some of the guess out of breeding operations. From this study it appears that the daughters' records alone are not nearly as efficient for predicting production of the daughters of bulls as are indexes based on a comparison of daughters' records with those of their dams.

Value of Pedigree and Certain Parts Thereof in Predicting Production of Bull's Daughters

Material	Range of Errors	Percentage With Less Than 5% Error	Percentage of Bulls Whose Daughters Exceeded Expectations	Average Error	Correlation Between Indicated Method at Left and Bull's Daughters Average
Guernsey Pedigree Index	−16 to +14	80	70	4.40	=.62 ± .07
Jersey Pedigree Index (Uncorrected)........	−52 to +18	20	20	15.79	=.19 ± .11
Jersey Pedigree Index (Corrected)..........	−41 to +13	37	20	12.06	=.41 ± .09
Jersey Sires' Daus. (Uncorrected)........	−40 to +14	20	20	16.01	=.45 ± .09
Jersey Sires' Daus. (Corrected)..........	−31 to +14	26	20	12.00	=.54 ± .08
Jersey Dams' Record...	−101 to +28	11	11	27.40	=.18 ± .11
Jersey Dams' Record Averaged with Sire's Daughters Average....	−55 to +16	28	20	15.94	=.28 ± .10
Jersey Sire's Dau. Average and Dam's Record (Uncorrected)....	−67 to +6	9	9	20.34	=.33 ± .10
Jersey Sire's Dau. Average and Dam's Record (Corrected) Averaged with Sire's Daughters' Average.............	−43 to +11	26	17	13.70	=.47 ± .09
Jersey 3 Nearest Sires (Uncorrected)........	−43 to +20	31	28	13.43	=.24 ± .10
Jersey 3 Nearest Sires (Corrected)..........	−52 to +10	37	26	10.98	=.46 ± .09
Jersey 5 Nearest Sires (Uncorrected)........	−41 to +26	31	37	11.70	=.15 ± .11
Jersey 5 Nearest Sires (Corrected)..........	−31 to +15	30	50	9.80	=.43 ± .09

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

The major part of the research program in bacteriology for this and several preceding years has been the study of the physiology of bacteria of the Coli-Aerogenes group. The Standard Methods of Water Analysis of the American Public Health Association employs the group as an indicator of the sanitary quality of a water supply. It must be pointed out, however, that the Standard Methods procedure is designed primarily to test filtered and treated municipal water supplies. Experience in this laboratory has been that the standard is too rigorous for the wells and springs that supply farms and rural homes. Certain authorities on water bacteriology maintain that, of the Coli-Aerogenes group, only *Escherichia coli* and perhaps closely related intermediates of the group are certain indicators of sewage pollution; and that *Aerobacter aerogenes* and closely related intermediates indicate only surface drainage, and if they indicate sewage pollution at all, it is so remote in time as to be harmless.

This laboratory is frequently faced with the necessity of deciding upon the quality of a water sample which would be condemned on the basis of the bacteriological test, but not on the basis of available information concerning the location, construction, and surroundings of the well or spring in question. The condemnation of a privately owned rural water supply frequently involves a serious financial problem to the owner, and it is for this reason that research in the physiology of the Coli-Aerogenes group was undertaken in the hope that more information could be obtained as to methods of differentiating members of the group, in order that a better understanding of their relative sanitary significance might result.

The Influence of Bile and Bile Salts on Aerobacter Aerogenes. (James E. Fuller.) A preliminary report has been made on this study (Mass. Expt. Sta. Bul. 339, 1937). The study was undertaken to investigate the premise of certain investigators that *Escherichia coli* may become *Aerobacter aerogenes*, and vice versa, as a result of environment. Since bile is an important constituent of the fecal mass in the human colon, it could be an important environmental factor in converting *Aerobacter aerogenes* to *Escherichia coli*, if the premise should be true. Twenty-five strains of *Aerobacter aerogenes*, originally isolated from water, were cultivated for five months in one percent, and in five percent, concentrations of bile and of bile salts (sodium glycocholate and sodium taurocholate). At the end of five months' incubation the reactions of the strains to the differential tests (Voges-Proskauer, methyl-red, sodium citrate, uric acid, and indol production), and their morphology and staining characteristics were unaltered. This research does not lend any support to the premise mentioned above.

The Effect of Bacteriophage on Escherichia coli. (Amedeo Bondi, Jr. and James E. Fuller.) This study, like the one above, was undertaken to investigate the stability of members of the Coli-Aerogenes group. Bacteriophage is an environmental factor which, when it acts on a susceptible bacterial strain, sometimes produces cultures quite different from the parent strain in appearance and behaviour. Several strains of *Escherichia coli* were subjected to the influence of a strain of bacteriophage which was specific for one of the strains, but not for the others. The biochemical reactions (lactose fermentation, indol production, and the methyl-red, sodium citrate, and sodium malonate reactions) were not changed. The strain subjected to the action of its specific bacteriophage yielded atypical colonies on nutrient agar and on Endo's medium. Subcultures from these atypical colonies were resistant to the action of the bacteriophage which had produced them, and were agglutinated by higher dilutions of a specific serum than were cultures of the same bacterial strain before it had been subjected to the action of the bacteriophage.

The Action of the Coli-Aerogenes Group on Erythrosin. (Ralph L. France.) The results of this study are published in *Zentralblatt fur Bakteriologie* II Abt., Bd. 97, 1937.

A Study of the Eijkman Test. (Ralph L. France.) A pure culture study of strains of the Coli-Aerogenes group indicate that the *Escherichia coli* strains are the only ones that produce acid and gas in the Eijkman broth at 46° C. However, certain strains of intermediates and *Aerobacter aerogenes* produce acid, but no gas, at 46° C. Further studies are being conducted to determine the extent of growth of strains of intermediates and *Aerobacter aerogenes* in the Eijkman broth, at 46°, 45°, 44°, and 43° C.

The Tolerance of the Coli-Aerogenes Group for Brilliant Green. (Ralph L. France.) No work has been done on this project since the last report of progress (Mass. Expt. Sta. Bul. 339, 1937). The project will be completed this year.

A Comparative Study of Proposed New Methods and the Standard Methods for Obtaining Bacteria Counts of Milk Samples. (Ralph L. France.) The results to date indicate that a 32° C. incubation temperature gives more accurate counts than the standard 37° C. temperature. The Bowers-Hucker plating medium does not appear to have any advantages over the standard medium when incubation is at 32° C.

A Comparative Study of Proposed New Methods and Standard Methods for Testing Oysters. (Ralph L France.) This project has been undertaken upon the request of Dr. C. A Perry, referee and chairman of the Standard Methods Committee for Oyster Analysis of the American Public Health Association. Work will be started as soon as a copy of the proposed new methods has been received from the referee.

Influence of Added Iodine and Kelp on Intestinal Flora of White Rats. (W. B. Esselen, Jr., James E. Fuller, and George S. Congdon.) It is generally conceded by authorities that the aciduric bacteria of the acidophilus type are preferable in the intestine to bacteria which decompose protein materials, since the latter produce products which are detrimental to the body when they are absorbed into the blood. This project was designed to study the influence of iodine and mineral elements and their salts on intestinal bacteria.

White rats were fed raw or pasteurized milk, both with and without added iodine. A similar experiment was run with kelp instead of iodine added to the milk. The addition of iodine or kelp to the milk did not appear to influence the ratio of aciduric to proteolytic bacteria. All of the milk diets increased the percentage as well as the numbers of aciduric bacteria; raw milk without iodine was less effective than were the other milk diets. There was no marked effect on the reaction (pH) of the feces of any of the rats. Gastric acidity of rats on the kelp supplement was higher than that of rats not fed kelp. Kelp in the diet did not significantly influence the amount of urinary phenol (considered indicative of intestinal putrefaction) or of conjugated phenols (considered indicative of the ability of the body to neutralize toxic phenols absorbed from the intestine). This is the completion of the study reported previously (Mass. Expt. Sta. Bul. 339, 1937).

Influence of Added Iodine on the Bacterial Flora of Milk. (George S. Congdon and James E. Fuller.) The influence of added iodine on the bacterial flora of milk was investigated. In addition, pure culture studies were made with bacteria inoculated into sterilized raw milk and into nutrient broth. Tincture of iodine U. S. P., Gram's iodine-potassium iodide solution, and Iodine Suspensoid (Merck) were the forms of iodine employed Gram's iodine solution was a somewhat more efficient germicide than the other two solutions, but it is less stable. Milk with a higher bacteria count required more iodine for its sterilization than did low-count milk. This is the completion of the study previously reported (Mass. Expt. Sta. Bul. 339, 1937).

The Action of Intestinal Bacteria on Ascorbic Acid (Vitamin C). (W. B. Esselen, Jr.) The purpose of this study was to investigate the reported destruction of Vitamin C by certain intestinal bacteria, and to attempt to discover the mechanism of the vitamin's destruction. Pure cultures of the bacteria employed were cultivated in media containing ascorbic acid. The results indicated that, instead of destroying Vitamin C, the bacteria actually exerted a protective action which varied directly with the suitability of the medium for bacterial growth and with the numbers of bacteria present. Lowered pH in the medium was not a factor in protecting the vitamin, and no correlation was observed between the ability of the bacteria to reduce methylene blue and the stability of the vitamin in their presence. The cultivation of the culture in atmospheres of carbon dioxide and of hydrogen respectively revealed that carbon dioxide apparently exerted a protective action on the vitamin, while hydrogen had no such action. The analogy is that the carbon dioxide produced by bacteria from readily fermentable carbohydrates can protect vitamins from destruction in the human intestine. The bacteria employed were several strains of the Coli-Aerogenes group and of the Salmonella group, and one each of *Eberthella typhi*, *Bacillus subtilis*, and *Proteus vulgaris*.

Laboratory Service. (Ralph L. France.) Following is a list of the numbers and types of examinations made during the past year:

Milk (bacteria counts)	1,398
Ice Cream (bacteria counts)	89
Water	119
Miscellaneous:	
Sediment (Milk)	16
Mastitis	1
Wash Water	12
Throat Swabs	15
Smears	3
Total	1,653

Bacteriological Study of Machinist Cutting Compound (James E. Fuller.) This survey study was reported in *Journal of Bacteriology* 34 (No. 2):241, 1937.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Effect of Soil Temperature on Gardenia. (L. H. Jones.) In a series of experiments carried on in the soil temperature tanks, it was determined that a chlorosis of gardenia may be induced at any time of the year by a soil temperature of 18° C. and less and develops more intensely directly as the soil temperature is lowered. The number of days necessary to induce chlorosis varied with the health of the plants at the time the temperature was lowered. Hard plants growing at medium temperatures developed chlorosis more slowly than soft plants grown at high temperatures. A sharp rise in soil temperature maintained for 13 days was sufficient to initiate the return of a healthy green color.

Soil temperature affected growth rates and the final size of the leaf. The rate of growth was inversely correlated with the intensity of the development of chlorosis. The size of the leaf was correlated with soil temperature directly as the soil temperature was increased.

Plants which had been growing at a high soil temperature and were suddenly subjected to a low soil temperature were unable to absorb enough water to maintain turgidity in the leaves. The plants wilted in sunshine but recovered turgidity at night. Recovery was complete in about two weeks.

Lowering the soil temperature to 10° C. or less caused a rapid senescence of the oldest leaves.

There were indications that a low soil temperature altered the vegetative or growing phase to a reproductive or flowering phase.

Soil Temperature as an Important Ecological Factor in Greenhouses. (L. H. Jones.) Investigations indicate that the real value of air temperature control in greenhouses may lie in its effect on soil temperature, for soil temperature has a greater influence on plant development than has air temperature. Knowledge of factors affecting soil temperature would lead to changes in practice that should maintain the desired soil temperature. There is a lag in the rise and fall of soil temperature as the air temperature is maintained high or low, which may be as much as four hours in benches and considerably longer in ground beds, and depends not only on the depth of soil, but also on the amount of moisture in the soil. There are two available instruments for measuring soil temperature. One is a soil thermometer similar to ordinary air thermometers, except that the bulb is protected by a pointed, perforated metal cap which is thrust into the soil. The other is a recording soil thermometer. The first gives the reading only at the time it is observed. The recording type reproduces all values on a chart for the duration of a week. An effort is being made to construct a maximum-minimum thermometer for soil work. Such an instrument will be of greater value than the type which gives no record of changes and will be less expensive than the recording type.

Root-System Development of Hardened Plants. (L. H. Jones.) Potted gardenia and rose plants which had become hardened by lack of nitrogen and frequent drouth conditions were slow to develop new roots and shoots when transplanted to a rich soil that was kept moist. However, when the hardened plants were watered with a dilute solution of ammonium sulfate (one ounce per gallon) five days before transplanting, there was a much greater increase in the number of roots and length of shoot development than when the plants did not have the nitrogen applied before transplanting. The results obtained from these tests indicate that there is an advantage for reestablishment of plants in applying nitrogen before the root system is disturbed.

Study of Diseases of Ornamental Herbaceous Plants Caused by Soil-Infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) Work under this project has involved a search for better methods for using old soil disinfectants as well as other chemicals, and for possible new soil disinfectants, which may have more nearly ideal qualities. The soil used was either naturally infested or artificially inoculated with Pythium and Rhizoctonia. *Rhizoctonia solani* Kuhn. used for test purposes during the past season was isolated from *Mentha Requienii* Benth. and *Cerastium tomentosum* L.

Undiluted vinegar, 200 to 235 cc. per sq. ft., has continued to give satisfactory control of damping-off. Worked into or mixed with the soil immediately before seeding, this has usually been safe enough although crucifers seem to be less tolerant of acetic acid (of which vinegar contains about 4.0 percent) than are the other plants used. Crucifers are less tolerant of formaldehyde also and the point is of some importance, for the family includes a number of the most popular ornamental plants: for example, species of Arabis, Cheiranthus, Hesperis, Mathiola, Aubrietia, Draba, Alyssum and Iberis. Treatments especially adapted to them are now being developed.

Other things being equal, the species most subject to injury by acetic acid or formaldehyde, applied to soil immediately before seeding, were those the seeds of which germinate most promptly.

About 8 cc. of acetic acid (80 percent), diluted to 300 cc. (per sq. ft. of soil), did not injure even crucifers when seeds were sown immediately after it was worked into the soil. By the prevention of some pre-emergence damping-off, this treatment usually improved germination as did also formaldehyde 6 cc. (in 500 cc. water) similarly used.

Formic acid appears to be a good soil fungicide and its use is now being further investigated. Seven cc. of formic acid (90 percent), diluted to 300 cc. (per sq. ft.) and mixed with the soil immediately before seeding, controlled damping-off very well, improved germination of all species with which it was used, and did not interfere with growth. It must, of course, be handled with care to avoid injuring one's skin.

Work with salicylic acid has been continued, for an application of 6 to 8 gm. per sq. ft. has, in the presence of fungi, usually improved germination; and this material, being a crystalline powder, has the advantage of being readily applied to soil without the necessity of first preparing either a dust mixture or a solution.

A pyroligneous acid, made from pine wood, was applied to soil at the rate of about 125 cc. per sq. ft., undiluted, immediately before seeding. This satisfactorily controlled damping-off without injury to the species of plants with which it was used, and its use in this way, without the addition of water, is now being studied further.

Some work has been done on the sterilization of soils, in closed containers, by the vapors of formaldehyde rather than by a solution. Soils so exposed to these vapors, for a few days, could not be used immediately without injury to seeds, but after being aired for two days, there was no injury to growth and, most fungi having apparently been killed, germination was improved.

There are soils in the trade which have been sterilized by the firms supplying them and, unless they later become contaminated, there is little or no damping-off in them. To lessen the cost of using such soil, the writer has diluted it with washed sand, up to half and half. No increase in damping-off resulted; and seedlings, up to that stage at which they are commonly transplanted, grew well without the addition of nutrient.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modifications of Environment. (W. L Doran.) Because of the interest of nurserymen in the effects of such growth substances as indolebutyric acid on rooting of cuttings, a paper on some of the writer's results was published in our Nurseryculture Bulletin vol. 2, no. 5 (September 15, 1937) and work along this line has been continued. Special attention is being given to the time of taking cuttings and the relation of season to the response to treatment.

Such treatments are unnecessary for the cuttings of many species which, if taken at appropriate times, root readily enough without treatment. This was true of the following species when cuttings were taken at the times of year mentioned: *Viburnum rhytidophyllum* Hemsl., *Cephalanthus occidentalis* L., *Buddleia Davidi* Franch., and *Stephanandra incisa* Zabel. in the first week of August; *Pachistima Canbyi* Gray, *Coronilla Emerus* L., *Helianthemum nummularium* L., *Chamaecyparis pisifera* Endl. var. *plumosa* Beiss., *Thuja occidentalis* L. var. *umbraculifera* Beiss., and *Juniperus Sabina* L. var. *tamariscifolia* Ait. in the third week of October; *Cytisus Beanii* Nichols., *C. purgans* Benth. & Hook., *Genista pilosa* L., *Vaccinium Vitis-Idaea* L., and *Calluna vulgaris* (L.) Hull. in the third week of November; and *Juniperus communis* L., *J. procumbens* Sieb., and *J. scopulorum* Sarg. var. *horizontalis* D. Hill in the last week of December.

Some other species and some of the above if taken at other times may root more rapidly if cuttings are treated, but not always in larger percentages finally. This was the effect, for example, of indolebutyric acid on Calluna and *Dorycnium hirsutum* Ser. It may, in fact, be principally by hastening rooting that such treatments improve the rooting of cuttings of some species, for cuttings which root more rapidly as a result of treatment are less likely to die unrooted than are cuttings which, without treatment, root more slowly. The life of unrooted cuttings is limited and they either root or rot. If they rot, it is partly because they did not root, but if they do not root, it is not necessarily and only because they rot; and such experience as the writer has had with these treatments does not indicate that they are fungicidal.

Species which not only rooted more rapidly, but also in decidedly larger percentages after treatment with indolebutyric acid than without it, when cuttings were taken at these specified times, included: *Passiflora racemosa* Brot. (last of June); *Ilex crenata* Thunb., *I. yunnanensis* Franch., *Cyrilla racemiflora* L., and *Pentstemon Scouleri* Dougl. (first of September); *Stewartia koreana* Nakai, and Franklinia (first of August). Similar treatment with indoleacetic acid (usually 0.10 gm. in 1000 cc. water for 24 hours or 0.05 gm. in 1000 cc. for 48 hours) improved the rooting of cuttings of these species: *Lespedeza formosa* Koehne (middle of October); *Taxus media* Rehd. var. *Hicksii* Rehd., *T. cuspidata* Sieb. & Zucc. var. *densa* Rehd., *Picea pungens* Engelm. var., *Chamaecyparis pisifera* Endl. var. *squarrosa* Beiss. & Hochst., *C. obtusa* Endl., *C. obtusa* Endl. var. *aurea* Beiss. and *C. obtusa* Endl. var. *nana* Carr. (last of December).

The importance of the time of taking the cuttings cannot be overemphasized whether or not cuttings are to be treated. Cuttings of *Picea glauca* Voss. var. *conica* Rehd. rooted better when taken in December than when taken in October and those taken in December were more benefited by these treatments.

Cuttings of many species, taken when they were, rooted equally poorly with and without treatments, there being no apparent benefit to the varieties of Norway spruce, for instance, when taken in December, or to several species of Rhododendron taken in November and December. This was true also of *Cotoneaster horizontalis* Decne., with cuttings taken the first of October, although cuttings of this species rooted well, even without treatment, if taken by the middle of June. Franklinia, similarly, rooted very poorly, with or without treatment, if cuttings were taken early in September, although their rooting was improved by indolebutyric acid when they were taken a month earlier. Generally speaking, and with some exceptions, cuttings of harder wood were less benefited by these treatments than were cuttings of the same species taken a little earlier.

If treatment with indolebutyric acid was ineffective, so, in most cases, was treatment with indoleacetic acid. Rooting of cuttings of *Genista pilosa* L. and of *Taxus cuspidata* Sieb. & Zucc. var. *Thayerae* was, however, benefited more by indoleacetic than by indolebutyric acid.

Although most cuttings were treated immediately before insertion, those of a few species were inserted without treatment, removed and treated two weeks later, and then reinserted. This was done with the thought that such a delayed treatment, if effective, may be useful in the case of cuttings which are not rooting as they should or which, for any reason, were not treated before the original insertion. Such treatment (with indoleacetic acid) improved the rooting of cuttings of Japan quince and of *Enkianthus subsessilis* Mak., but was of no value in the case of cuttings which had begun to decay before treatment, as had those of *Lonicera alpigena* L., and was slightly injurious to cuttings of buttonbush which had already begun to develop roots.

Treatment with formic acid (0.2 or 0.4 gm. in 1000 cc. for 24 hours) improved the rooting of cuttings of *Viburnum dilatatum* Thunb., *Ilex crenata* Thunb., and *Hypericum* sp. The use of this chemical is now being further investigated, for the writer has found that, in greater concentrations, it has fungicidal properties and it is less expensive than the chemicals above mentioned.

With a view to preventing infection of cuttings in sand-peat moss inoculated with Pythium and Rhizoctonia, basal ends of some cuttings were dipped (dry) in zinc oxide powder. This proved to be very injurious to cuttings of all species with which it was used.

Copper carbonate, 5.5 gm. per sq. ft., mixed with this medium before the insertion of cuttings, was no less harmful, the only species not much injured by it being two barberries, *Berberis Julianae* Schneid. and *B. stenophylla* Lindl.

Acetic acid does not remain in the soil long enough to protect against damping-off the seeds and seedlings of species which germinate slowly. Copper oxalate, 6 gm. per sq. ft., applied to soil before seeding, gave much better results with *Sciadopitys verticillata* Sieb. & Zucc., seeds of which germinated 3 months after seeding.

Chemical Soil Surface Treatments in Hotbeds for Controlling Damping-Off of Early Forcing Vegetables. (W. L. Doran with E. F. Guba.) A soil disinfectant may be applied to the soil (1) before seeding, (2) after seeding, but before germination, or (3) after the emergence of seedlings. The first of these methods has been most common in the past, but there is a continued demand for more convenient methods and these may include treatments to be applied later.

The writers have found no treatment effective against damping-off which at the same time is safe to use after the emergence of seedlings, which means with living plants. Vinegar, in amount too small to protect against damping-off, was injurious to seedlings of most species even when variously diluted.

Such a treatment could not improve germination anyway; and more attention has therefore been given to the application of a soil disinfectant immediately after seeding and before germination.

The important point is not so much when as how a chemical is applied to soil, there being often no more than ten minutes' difference between the times of application of treatments before and after seeding. It should be further understood in this connection that a chemical applied to soil after seeding cannot, because of the earlier presence of the seed, be worked into or mixed with the soil and that it is, therefore, more concentrated near the soil surface and, consequently, near the seeds.

That being the case, the possibility of injury to the seeds is greater and applications which were safe enough if applied to soil immediately before seeding were injurious in some cases if applied immediately after seeding. Thus as little as 4 cc. formic acid (90 percent) diluted to 250 cc. (per sq. ft.) was harmful if applied to soil immediately after seeding, although 7 cc. applied before seeding was not injurious to the same species. Formaldehyde 7 cc. and acetic acid (80 percent) 8 cc. per sq. ft., or either one of these diluted with 5 times those volumes of water and applied to soil immediately after seeding, was injurious to species to which they were quite harmless if mixed with soil before seeding.

Treatments applied after seeding were generally least injurious to species the seeds of which germinate relatively slowly, as do those of pepper, and more injurious to seeds, such as cabbage, which germinate in fewer days or before enough of the volatile chemical has escaped from the soil.

When formaldehyde is diluted 1:300 and applied to soil at the rate of 0.75 qt. per sq. ft., there is only about 2.3 cc. formaldehyde per sq. ft.; but even this light application, when made immediately after seeding, prevented most early damping-off. It did not injure tomato, eggplant, pepper or lettuce, but it did injure cress, the only crucifer with which it was used. It was not proved that such a light application would be for long effective in preventing fungi from growing up from the soil below, but such methods are convenient, if sufficiently effective, and they are being further investigated.

Vinegar 175 cc. (per sq. ft.) diluted with an equal volume of water and applied after seeding, was harmful to cabbage; but 220 cc. similarly used did not injure pepper or several species of Opuntia, the seeds of which, like those of pepper, germinate relatively slowly. This amount of vinegar, 220 cc., prevented most damping-off, but more than 200 cc. is not ordinarily to be used in this way with safety to most species. The use of vinegar after seeding appears to be feasible and details of method and dosage are now being further developed.

Pyroligneous acid is being similarly used experimentally and with encouraging results

Different chemical powders were dusted on lettuce and cabbage seedbeds in flats after firming the soil over the seed, and again upon emergence. On lettuce, the stand was improved over the check 11 percent with red copper oxide, 5 percent with Basi-Cop, 1.6 percent with Vasco, 6 percent with calomel, and 2 percent with a 20-80 monohydrated copper-lime dust. On cabbage, the stand was improved 18 percent with Vasco, 10 percent with zinc oxide, and 15 percent with a 20-80 copper-lime dust.

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.) Since the previous report, the tomato resistant to Cladosporium leaf mold has been crossed back to the Waltham Forcing tomato for increase in size. Two generations of these crosses have been grown and selected for resistance and quality. The resistance of these tomatoes has been confirmed by other investigators in the United States and other countries. Their reports would indicate the occurrence of but one strain of the fungus.

Carnation Blight caused by Alternaria dianthi S. & H. (E. F. Guba, Waltham.) The relation of the newer varieties of carnations to blight was studied at Waltham, and 72 distinct varieties of carnation were grown at the Jahn greenhouses at East Bridgewater to observe their reaction to branch rot caused by *Fusarium dianthi*, a serious parallel problem, in anticipation of the preparation of a performance chart of the behavior of varieties to both *Alternaria dianthi* and *Fusarium dianthi*. All the Boston Ward types are very susceptible to both organisms, but their superior quality otherwise may justify efforts at breeding for disease resistance.

Causes and Control of Decay of Winter Squash in Storage. (E. F. Guba and C. J. Gilgut, Waltham.) Comparative studies were made of storage conditions, amount of squash decay, and loss from shrinkage. The squashes used in these studies were all from the same field. In a heated storage with the temperature averaging 57.3° F. and the relative humidity 62.0 percent, there were 21.3 percent infected or decayed squashes and the shrinkage in weight was 9.2 percent. In two other storages heat was employed only to avoid freezing. In one of these with the average temperature and humidity respectively 44.4° and 72.4 percent, decay and shrinkage were respectively 4.1 and 9.4 percent; while in another with average temperature and humidity at 44.4° and 83.9 percent, decay and shrinkage were respectively 14.3 and 7.3 percent.

Miscellaneous Tests and Experiments. (E. F. Guba and C. J. Gilgut, Waltham.)

1. *Control of the Begonia Leaf Nematode* (*Aphelenchoides fragariae*). All stages of the nematode in the leaves are killed in water of a mean temperature of 115° F. (5 minutes), 117½° F. (3 minutes), 118½° F. (2 minutes), and 120½°F. (1 minute). Submersion of plants in water at temperatures of 121-120° F. for 1 minute, 119-117° F. for 2 minutes, or 118-115° F. for 3 minutes, is recommended for infested stock, and the eradicative treatment should be made not nearer than

3 months to the marketing season. The same interval-temperatures proved safe for leaf cuttings. Sanitary and cultural methods within the limits of good plant growth and commercial practice are not effective in arresting the progress of the disease.

2. *Apple Scab Control.* Five brands of wettable sulfur of different sulfur content ranging from 30 to 98½ percent, and varying in particle size from 0.9-6.3 microns to 3-4.5 microns with different brands, were compared on an equivalent sulfur basis in a full schedule of treatments with the official spray schedule of liquid lime-sulfur and wettable sulfur for scab control and foliage tolerance. The coarsest and finest wettable sulfurs gave the poorest and best control, respectively. Injury to the foliage, which was severe, occurred only from liquid lime-sulfur. The materials and results are tabulated as follows:

Material	Sulfur Content Percent	Dilution Pounds in 100 Gallons	Scabby Apples Percent	Average Number of Infections per Scabbed Apple
Linco	55	3.2	No apples	No apples
Hood	98.5	1.8	13.3	3.3
Magnetic	98.5	1.8	23.8	3.3
Flotation	40	4.5	2.5	1.0
Kolofog	30	6.0	8.3	5.0
Official schedule			0.0	0.0

3. *Vegetable Seed Treatments.* Soaking of celery seed in corrosive sublimate solution (1-1000) for 20 minutes, usually recommended as a disease control measure, was found in a series of tests to be definitely harmful to the seed. The mean stand of plants was reduced approximately one half by the treatment.

A test of different chemical treatments of vegetable seeds for damping-off control was conducted and the results embodied with the data of previous years. The preferred seed treatments for controlling damping-off, based on these tests, are indicated as follows:

Red Copper Oxide	Semesan	Zinc Oxide
Beet	Bean (snap)	Bean (lima)
Carrot	Cabbage	Parsnip
Cucumber	Cauliflower	Radish
Eggplant	Corn	Turnip
Lettuce	Onion	
Muskmelon	Pea	
Pepper		
Spinach		
Squash		
Tomato		

4. *Resistance of Cucumbers to Powdery Mildew* (*Erysiphe cichoracearum* DC.). This disease is a major problem in the culture of greenhouse cucumbers. A test in cooperation with Prof. R. E. Young in search of resistance among 169 types of cucurbits, mostly cucumbers, supplied by the Division of Plant Exploration and Introduction, United States Department of Agriculture, showed a high degree of susceptibility by all except *Cucumis Melo* L. var. *flexuosus* Naudin, the snake melon, which was resistant but which does not cross with the cucumber. Studies will be made of other types.

5. *Copper Spray Tests on Cucumbers, Muskmelons and Tomatoes.* These crops were used to test the merits of newer copper fungicides. This year Copper Hydro 40, Coposil, Dow Copper Fungicide, Basi-Cop, Cupro-K, Cuprocide 54,

Copper Zeolite, Copper Oxychloride A, and Bordeaux 4-4-50 were compared on the basis of copper content. In the absence of much disease, yield was best without any treatment with cucumbers and tomatoes, while Basi-Cop ranked first with melons. On cucumbers, Cuprocide 54, Bordeaux 4-4-50, and Cupro-K showed the poorest in appearance and yield; on melons, appearance was noticeably inferior only with Bordeaux, while the yields were poorest with Copper Oxychloride, Bordeaux 4-4-50, and Cuprocide 54. With tomatoes, the yields were poorest with Coposil, Copper Zeolite, and Burgundy Mixture, and this was not associated with any greater amounts of early blight.

Diseases of Trees in Massachusetts. (M. A. McKenzie and A. Vincent Osmun.) Investigations of the diseases of shade and ornamental trees in Massachusetts, begun in the summer of 1935 and continued throughout 1936, were carried on during the past year. Field and laboratory studies centered around the diseases of elm.

In a recent elm census report, the value estimated for the elms in four Massachusetts cities and towns was conservatively placed at $7,300,000. However, in the final analysis, all fiduciary ratings fail in an actual evaluation of elms in New England. Indeed to no small degree, the elms may be said to identify New England, and Massachusetts occupies an important place in this arboricultural identification. Any threat to the elm in this State, therefore, is cause for alarm, and since 1930, when the Dutch elm disease was first discovered in America, all persons interested in our principal shade tree have become increasingly concerned as the number of elms known to be affected by this disease has steadily mounted. Up to the present writing (December 1937), the disease has not been found in Massachusetts. Nevertheless, an important part of the work on tree diseases covered by this report has been the preparation of a bulletin[1] containing basic information concerning the characteristics and spread of the Dutch elm disease.

It is to be hoped that if the public is adequately informed on the disease, the chances of early report and prompt diagnosis of trees suspected of infestation will be conspicuously favored. Since no adequate treatment is known for affected trees, their prompt removal is imperative in any attempt to control the disease. Such a program is in operation in states where the disease has been discovered and at present, as far as is known, the number of affected elms left standing is almost negligible. The hopeful opinion that control of the disease is not impossible has been expressed by persons charged with the responsibility of the eradication program in the infested areas. However, the privilege of this statement entails the responsibility of constant vigilance, and in actuality control is a corollary to patrol. Any encouragement in the present favorable outlook is justifiable only as long as constantly changing conditions are studied and recorded.

It would be extremely difficult if not impossible to designate a single feature of the control program in infested areas as the one responsible for its apparent current success, and no attempt will be made to do so. One principal result of the program in uninfested areas like Massachusetts, as well as in areas where the disease is present is profoundly evident: a demand on the part of the public for information and work programs for general tree improvement. Sustained and increasing public interest in tree problems is apparent by the number of inquiries on these matters received from the citizens of Massachusetts. The adoption of a program for the promotion of the health of the tree population comparable to the public health programs for the human population has resulted in many communities throughout the State. Many tree diseases, in particular the Dutch elm disease, may be identified only by laboratory diagnosis. Since the establishment of the Shade Tree Laboratory in June 1935, approximately 5700 specimens have been received for diagnosis. During 1937, laboratory studies of more than 700 specimens, including collections by 4 field men, were completed by cultural and microscopical methods. Sixty-six diseases of 32 hosts, including 12 diseases of elm, were studied during the year.

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[1] Published as Mass. Agr. Exp. Sta. Bull. 343, May 1937.

Experiments, initiated in 1936, on potted elms of several species inoculated with fungus parasites of elm known to be present in Massachusetts have been continued in the greenhouse during the past year.

A detailed study[2] of the State-wide distribution of elm wilts associated with Cephalosporium and Verticillium was completed by Miss Eunice M. Johnson, Institutional Fellow in Botany.

Cytospora Disease of Spruce. (C. J. Gilgut, Waltham.) Experiments for the control of this disease have been inaugurated with diseased trees of Colorado blue spruce on a private estate in Holyoke and a cemetery in Worcester. The appearance of the trees has been much improved by removal of diseased and dead limbs, and in Holyoke by a summer application of an inorganic fertilizer. The trees in both locations are to be fertilized and sprayed in the spring of 1938.

DEPARTMENT OF CHEMISTRY

W. S. Ritchie in Charge

Cooperative Analytical Service. (The Department.) Service to outside departments and individuals has been continued. Samples of milk from Harvard Medical School were analyzed for traces of copper with the view of evaluating methods. Thirteen samples of so-called "foreign breads" collected in Boston in connection with the work on diabetes of the Boston City Hospital were analyzed for total carbohydrate. In addition the proximate analysis was determined. The results of the analysis of these breads are expected to be published in a short time.

Cooperation has continued with the workers at the Waltham Field Station. In particular, certain paint samples (about 18 in number) have been analyzed for soluble zinc and sulfur salts in connection with the "burning" of plants following fumigating with sulfur. Details of this work appear in the reports of that group.

Testing Analytical Methods. (The Department.) The methods for determining iron, copper and manganese, previously reported, have received continued study to the end that they may be made simpler, more accurate, and more rapid.

Acting as associate referee for methods of determining zinc in small quantities, a method was developed and reported to the Referee on Metals in Foods. By this method the ashed sample is dissolved in 2N hydrochloric acid, since the wet combustion method (sulfuric and nitric acids) was found to be unsuitable. To this acid solution, the carbamate reagent (sodium diethyl dithiocarbamate) and the dithizone (diphenyl thiocarbazone) are added in excess and shaken with carbon tetrachloride. The latter was found to be more agreeable to use than either chloroform or amyl alcohol, solvents sometimes used in this connection. The organic solvent containing some of the interfering metals is discarded and the aqueous solution of the zinc is treated with ammonium citrate, ammonium hydroxide, the carbamate reagent and an excess of dithizone. This is again shaken with carbon tetrachloride, which is washed with dilute (0.02M) ammonium hydroxide, and then compared to a standard prepared in the same manner. Such a method shows practically a complete recovery between 5 and 25 gammas of zinc. For larger amounts of zinc, the use of suitable aliquots of the sample was recommended rather than the development of a different procedure. Details of the method will appear in the Journal of the A.O.A.C.

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[2] Published in Plant Disease Reporter 21:3:58-59. Feb. 15, 1937.

Methods for the determination of boron are now under consideration since it is becoming more and more evident that this element is a factor to be considered in certain crops, and methods for measuring small amounts are necessary.

Vitamin C (ascorbic acid) may be determined satisfactorily in comparison with the bio-assay by titration with a dye, 2, 6-dichlorophenolindophenol. The dye has usually been standardized against either pure ascorbic acid or lemon juice. A new method has been devised for the standardization of the dye, agreeing very well with the two methods above, based on the quantitative oxidation of iodide to iodine. The iodine liberated is titrated with standard sodium-thiosulfate. This method is much simpler, involving only one titration, once the standard solution of sodium-thiosulfate is prepared. This method was presented and discussed at the recent meeting of the American Chemical Society at Rochester, New York, and will appear, in abstract, in the journals of that organization.

The Iron, Copper, Manganese, and Iodine Content of Fruits and Vegetables Used as Human Foods. (E. B. Holland, C. P. Jones, and W. S. Ritchie.) This project, having for its objective an analytical survey of common foods, including grains, fruits, vegetables, nuts, etc., has been continued. Sixty-two new samples have been collected and prepared for the analysis which is under way. The proximate analysis is being determined as well as the content of iron, manganese, copper, iodine, phosphorus, and zinc.

With the cooperation of the workers at the Waltham Field Station, it has been possible to get samples of vegetables including celery, beets, carrots, cabbage, and spinach, whose history is known, i.e., the soil type producing them, fertilizer treatment, irrigation, and other cultural practices. It is expected that such samples will reflect the influence of these treatments assuming that there is an effect.

Approximate Range in Some Ash Constituents
In Terms of Dry Matter

	Crude Ash		Iron ppm	Copper ppm	Manganese ppm	Phosphorus ppm
	Acid Soluble %	Acid Insoluble %				
Major fruits....	1– 3.5	0.00–0.03	10– 80	5–15	tr.– 10	200– 1800
Berries........	1– 5	0.00–0.25	40– 180	5–40	20–170	600– 2900
"Garden" fruits	4–11	0.00–0.15	20– 130	5–40	tr.– 35	1200– 5000
Leaf and stem vegetables...	9–23	0.02–2+	25–1000	5–35	tr.–250	3000–10000
Root vegetables	4–15	0.02–0.10	20– 200	5–40	tr.– 35	1400– 5000
Cereals[1].......	1– 3	0.00–0.50	30– 120	5–15	tr.– 60	900– 4500
Nuts..........	2– 4	0.00–0.01	tr.– 150	5–25	10– 45	2500– 7500
Peas and beans	4– 8	0.00–0.10	75– 100	5–25	10– 35	4500– 7000

[1] Excluding unhulled grains.

The completion of the analyses of the samples now in the process should, with a few additional ones, finish this survey.

Absorption by Food Plants of Chemical Elements of Importance in Human Physiology and Nutrition. (E. B. Holland, W. S. Ritchie, and W. S. Eisenmenger.) Work on this project was confined to an association with the investigators at the Waltham Field Station. Tomatoes and lettuce were grown in the greenhouses rather than in the open and were fertilized with compounds of iron, manganese, copper, and iodine. In the case of the tomatoes both the vines and the fruits were saved. Growing the vegetables under glass has the advantage that the samples are cleaner and freer from soil than when grown in the open. Since the analyses are dealing with minute quantities of the elements, freedom from soil particles is important. The samples thus obtained were added to that group being analyzed in the previous project.

The Carbohydrates in Kentucky Bluegrass. (Emmett Bennett.) The procedure and outstanding results of previous years have been given in the Annual Reports of 1935-36. Data obtained in 1937 indicate that the content of structural carbohydrates increases with maturity and that these values are greater in the morning than at night; that the content of sucrose decreases with maturity but is greater at night than in the morning. Results of this investigation will soon be ready for publication.

Hemicelluloses of Tobacco Stalks. (Emmett Bennett.) A polyuronide hemicellulose from the cured stripped stalks of Havana seed tobacco has been isolated and studied. Upon hydrolysis the polyuronide yields xylose as the chief sugar. Details of this study have been published in *Industrial and Engineering Chemistry* (*Industrial Edition*) 29: 933, 1937.

Bacteriostatic Effect of Lignin. (Emmett Bennett.) Because of the bacteriostatic effect isolated lignin has been known to exert on decomposing plant material, it was believed that the intestinal flora of the rat might be changed by the ingestion of a diet high in lignin. Thus far results obtained in feeding a small number of rats do not indicate a definite change in the intestinal flora. Limited data, however, indicate that the ingestion of a high lignin diet by the rat is accompanied by losses in carbohydrate and nitrogen fractions. The lignin ingested may be recovered almost within limits of experimental error. The experiment is to be repeated with a larger group of animals during the coming year.

The Vitamin A Content of Pasture Grasses. (W. S. Ritchie and J. G. Archibald. Cooperative with Animal Husbandry.) In 1936 the vitamin A content was determined in samples of sheep fescue, Rhode Island bent, bluegrass, red top and timothy. The work of 1937 continued the assays for the vitamin A content of these grasses from both fertilized and unfertilized plots. Duplicate samples were available from these plots during the early growing season (June) and during the later period of growth (August). Samples of orchard grass and sweet vernal were added to the five reported on in 1936.

The data indicate that, generally speaking, the vitamin A content is higher in the grasses from the fertilized plots than from the unfertilized. The seasonal variation does not seem to be as great as that attributed to the application of commercial fertilizers.

Chemical Changes in the Cooking of Vegetables. (Monroe E. Freeman and W. S. Ritchie.) Chemical factors contributing to texture rating of cooked potatoes were investigated in two mealy and two waxy varieties. (These terms are used here according to definitions outlined in Maine Agricultural Experiment Station Bulletin 383, p. 344.) The four samples were obtained, in part, on the open market and came from different localities. The same varieties have since been grown in one plot during the summer of 1937. The data reported here were drawn only from the first four samples, and the tentative conclusions may necessarily be modified when the complete data are assembled.

Starch and dry matter were found to be closely correlated with texture after storage periods of three months and five months. This relationship was not evident from samples analyzed before the storage periods.

Previous workers have been unable to relate pectin fractions with texture of cooked potatoes. It has been found that the usual methods of pectin analysis and fractionation, originally devised for other types of plant material, could not be applied to potato without modification. Modified methods were devised that eliminated the protein and starch contaminants. These methods demonstrated that all potato samples tested — raw, baked, and steamed — contained very nearly 2 percent total pectin regardless of variety or texture. A fraction usually designated as calcium pectate ranged from 0.2 percent to 0.5 percent, with no apparent relation to texture or variety. The so-called "proto pectin" (acid soluble) could be completely extracted from potatoes in 12 hours by water at 85° C.

Additional data suggest that the larger part of the pectin in potato is so loosely bound that it is hardly comparable to the "proto pectin" fraction in other types of plant material. The total amount of this fraction, however, is not related to texture. While small amounts of pectin can be obtained by exhaustively extracting (mortar and pestle) fresh tissue with cold water, no pectin was extracted from dried, finely ground samples by water at 37° C.

Preliminary results indicated that the so-called "proto pectin" fraction was more loosely bound in mealy potatoes than in waxy varieties. This allowed a means of relating pectin to texture. Under certain conditions mealy varieties, cooked and raw, gave two to three times as much pectin as waxy varieties.

The usual method for drying potato samples did not increase the amount of soluble pectin through enzyme hydrolysis. On the other hand, a boiling ethanol dip, used presumably to halt this enzymatic hydrolysis, actually rendered water soluble (37° C.) 20 percent of the total pectin.

Cooking increased the water soluble (37° C.) pectin fraction from 0 percent to 70 percent of the total pectin. Starch (including dextrin) decreased to some extent. Reducing sugars increased slightly on cooking. Other data have been obtained, and experiments are in progress concerning the effect of storage on these and other relationships

Possible changes in the potatoes due either to storage or to cooking or both are also being followed by the "in vitro" methods suggested by Horwitt, Cowgill, and Mendel. These methods were first used and reported on leafy material (spinach). It is likely that some modification of the method will be necessary since with potatoes (a starchy product) the crude fiber as determined is practically the equivalent of the total carbohydrate. Using the method with such a sample as spinach, the carbohydrate (starch, etc.) would apparently be included as part of the crude fiber.

In addition to the work on the potato, possible changes in peas as a result of storage and cooking are being studied. For this purpose samples were obtained from the Birds Eye Frosted Foods Corporation during the past summer. The control sample represented the fresh peas in the pod. These were shipped to the laboratory where they were shelled and dried under suitable conditions. Samples from the same field were canned and frozen and stored under these conditions. These are being withdrawn from storage at definite intervals and prepared for analysis. Comparisons are to be made on the basis of the "in vitro" analysis mentioned above. Complete data are not available since storage periods are not yet finished.

Physical and Chemical Properties of Mosaic Viruses. (Monroe E. Freeman.) Eleven specimens of virus-infected tomato plants collected in commercial greenhouses in Massachusetts were examined. Ordinary tobacco mosaic virus was the only agent identified. Although abnormal symptoms were noted in some test plants, other agents were not found.

Connecticut Broadleaf tobacco seedlings were found to be the most successful test plants for the potato vein banding virus. Other varieties and strains of tobacco developed the typical symptoms more slowly and in many cases the symptoms were not distinct. No test plants could be found for this virus that would produce local lesions suitable for semi-quantitative assay. Plant juices containing this virus clarified by freezing, filtering, or low-speed centrifuging lost to a large extent their ability to infect tobacco seedlings. The evidence seems to suggest that most of the virus is associated with the chloroplasts or the heavier particles of the cellular debris. Experiments on this phase and on the effect of various chemical reagents are in progress.

The Effect of Storage and Processing on the Carbohydrates of Some Varieties of Edible Onions. (Emmett Bennett.) The project was created for the purpose of characterizing the carbohydrates of the onion and ascertaining the changes in this group which have been effected by prevailing storage conditions and by cooking.

Samples of U. S. No. 1 onions, grown from both seed and sets under similar conditions, were obtained from the Frank D. Hubbard Farms, Sunderland, Massachusetts. Representative samples of both types have been stored under varied conditions. To date, December 16, 1937, practically all of the onions grown from seed have sprouted regardless of storage conditions. Raw and cooked onions of both types have been prepared for analysis. Analytical data will not be available until after the storage period.

Lignin and Its Relation to the Absorption of Minerals by Plants. (Emmett Bennett.) This project is intended to reveal more of the chemical nature of lignin and to ascertain to a better degree the functions, if any, of the lignin in the soil with respect to plant nutrition. Lignin for this purpose has been isolated from corn cob and purified. Data are not yet available because of the short time this project has been in progress.

The Nutritive Value of Rare Elements in Plant Nutrition. The Comparative Nutritive Effects of Copper, Zinc, Chromium, and Molybdenum. (H. R. DeRose, W. S. Eisenmenger, and W. S. Ritchie.) The report of work on this project is given in the report of the Department of Agronomy.

Changes in Frozen Meat During Storage. (W. S. Ritchie.) This project had for its objective the determination of the changes, chemical and physical, occurring in meat during storage at freezing temperatures.

Samples for the work now in progress originated at Purdue University as the result of a feeding trial with hogs. The hogs were slaughtered and processed by Kingan and Company of Indianapolis and frozen by the Birds Eye Frosted Foods Corporation of Boston. Samples were furnished immediately on the killing of the hogs and again after freezing for a week or ten days. Subsequent samples from the same group of animals will appear at intervals of three, six, nine and twelve months. The work in progress includes the determination of the vitamin B and G content of the meat, the biological and growth-promoting value of its protein, tenderness, and nitrogen fractions as well as the usual analysis for total protein, fat, ash, and water.

The Nutritive Value of Chocolate Milks. (William Mueller and W. S. Ritchie.) (Dairy Department cooperative with Experiment Station Chemistry.) The details of this project will be found in the reports of the Dairy Department.

THE CRANBERRY STATION
East Wareham, Massachusetts

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Grape Anomala (*Anomala errans* Fab.). Early in May, 1937, two to three acres of the Santuit bog of the Smith-Hammond Co. in Mashpee were found to be infested seriously with grubs of this insect. Beetles were reared from some of these grubs in June. Many grapevines were growing near the infested bog. This is the third bog that has been found badly affected by this pest during the last few years.[1] As the species completes its life cycle in a year, the grubs of an infestation do not vary much in size. They look much like those of the cranberry white grub (*Phyllophaga*), but the hind part of the abdomen does not appear dark, because of its contents, as does that of the grub of that species.

Cranberry Weevil (*Anthonomus*). Clear, very high-grade pyrethrum dust (made from flowers grown in Kenia), applied on a warm day early in June at the rate of 100 pounds an acre, gave a good kill, thus confirming the results obtained with this material the year before.[2]

A spray of 15 pounds of derris powder (4 percent rotenone) and one half pound of Areskap in 100 gallons of water, used at the rate of 400 gallons an acre on August 3, failed to give a good kill.

Fire Beetle (*Cryptocephalus incertus* Oliv.). This beetle infested severely and extensively four different bogs — one in Carlisle, one in Lakeville, one in East Middleboro, and one in East Wareham — during the season, thus being far more troublesome than ever before. All but one of the bogs so far known to have been much infested with it have been flooded during the winter but not flowed in June. It has been found attacking severely the foliage of the Howes, Holliston, Bugle, and Aviator varieties, but does not infest Early Black vines much even where they grow close to other vines badly infested. The beetles feed much more on the upper surface than on the under side of the cranberry leaves and more near the margins than toward the middle of the leaf surface. They also excavate or eat around some of the new terminal buds of the vines and so directly reduce the crop of the following year somewhat. They feed much more in August and early September than later, when they are less active because of the lower temperatures. They were also abundant in places on the foliage of the swamp blueberry,[3] black huckleberry,[4] and beach plum.[5]

Clear, high-grade pyrethrum dust (0.9 percent pyrethrin content), applied to an infested bog at the rate of 100 pounds an acre in the middle of a warm day (Sept. 4, 1937) when the beetles were very active, killed less than half of them. A spray of 2 pounds of lead arsenate in 100 gallons of water, applied at the rate of

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[1] Mass. Agr. Expt. Sta. Bul. 339, p. 36, 1937.

[2] Mass. Agr. Expt. Sta. Bul. 339, p. 37, 1937.

[3] *Vaccinium corymbosum* L.

[4] *Gaylussacia baccata* C. Koch.

[5] *Prunus maritima* Wang.

250 gallons an acre, killed nearly all the beetles. This poison should be applied before the middle of August so that it will not remain in too great quantity as a residue on the berries when they are picked.

One grower treated a bad infestation of this insect on August 30, using 6 pounds of lead arsenate in 100 gallons of water and applying 250 gallons to the acre. Some heavy rains fell on the treated area during September, two of them lasting all day. The berries were picked Oct. 2 and many of them showed spray residue then. What seemed to be a sample with about the maximum amount of residue was analyzed by the Fertilizer and Feed Control Division of the station at Amherst with the following results:

.0255 grains of lead per pound of fruit
.01606 grains of arsenic trioxide per pound of fruit

A similar sample analyzed by Arthur D. Little, Inc., showed .006 grains of arsenic trioxide per pound. Another sample, left unpicked until the bog had been flooded for five days after the general picking was done, was found by Arthur D. Little, Inc., to show only .001 grains of arsenic trioxide per pound. It seems from this that several days flooding will do much to remove an arsenical residue from cranberries.

As the experiment station analysis showed both lead and arsenic residue substantially above legal tolerance, special apparatus was devised and 700 barrels of Howes berries were washed with a 2 percent solution of hydrochloric acid and then thoroughly rinsed. They were then dried at the drying plant of the A. D. Makepeace Co. and stored in a screenhouse from two weeks to a month. They kept well and were finally marketed successfully as fresh fruit.

Cranberry Fruitworm (*Mineola*). A spray of 8 pounds of derris powder (4 percent rotenone) and 2 pounds of soap in 100 gallons of water, applied at the rate of 400 gallons an acre on July 10 and again on July 20, controlled this pest almost completely on a bog where the worms took 40 percent of the crop on untreated check areas.

Ten pounds of cube powder (4 percent rotenone) and 2 pounds of soap in 100 gallons of water, applied at the rate of 400 gallons an acre, also gave good control.

Goulac, Ultrawet, calcium caseinate, SS-3, Ortho liquid spreader, coconut-oil soap, and resin fish-oil soap were tried as spreaders for the derris and cube sprays, the soaps giving the best results.

It seems that with either derris or cube powder, two sprays are advisable for control of the fruitworm, one to be applied when all but about a quarter of the bloom is past and the other about ten days later. Small sample lots of the berries should be examined before a bog is sprayed to determine the abundance and condition of the fruitworm eggs present.

Impregnated Pyrethrum Dust. The pyrethrum dust generally used by cranberry growers is the flower heads of the pyrethrum plant ground fine. It is thought that only the pyrethrins on the surfaces of the particles of this dust are effective against insects and that much more of these toxic principles is locked up in the interior of the particles where they cannot function. Pursuant to this reasoning, some manufacturers have prepared so-called impregnated or activated pyrethrum dusts in which the pyrethrins are placed on or brought to the surface of the particles. These dusts contain a considerably smaller percentage of pyrethrins than is present in high-grade pyrethrum dust obtained by grinding the flower heads, and so can be sold for less. Considerable attention was given to testing these dusts in comparison with high-grade pyrethrum dust as controls for gypsy moth caterpillars and blunt-nosed leafhoppers (*Ophiola*). As a general result of these tests, it may be said that the impregnated dusts, properly prepared and applied, can probably be relied on to check these pests as effectively as the high-grade pyrethrum dust (0.9 percent pyrethrin content), with a material saving in cost. Those who buy these dusts, however, should realize that they are putting themselves more fully in the hands of the manufacturers than they have been in buying the dust used heretofore.

Prevalence of Cranberry Pests. Notes on the relative general abundance of pests on Cape Cod cranberry bogs in the season of 1937 follow:

1. Black-headed fireworm (*Rhopobota*) considerably less prevalent than usual.
2. Fruitworm (*Mineola*) much less abundant than usual, doing probably as little harm as in any season during the last 33 years and finishing its work very early.
3. Weevils (*Anthonomus*) more prevalent than usual, especially on the outer part of the Cape.
4. Fire Beetle (*Cryptocephalus*). See above.
5. Gypsy moth even more destructive in Plymouth County than in 1936. but less so in Barnstable County than in recent years.
6. Tipworm (*Dasyneura*) considerably more prevalent than usual.

Control of Cranberry Bog Weeds. (Chester E. Cross.) This investigation was carried on in 1935 and 1936 by Dr. William H. Sawyer. In 1937 nearly 800 different weed plots were given various treatments with chemicals. Ammonium sulfate, copper sulfate, iron sulfate, kerosene, kerosene emulsions, sodium arsenate, sodium arsenite, sodium chlorate, sodium chloride, and sodium nitrate were tested variously as weed killers. The following were the more important results of this work:

1. A spray of half a pound of sodium arsenite in 100 gallons of water, applied after mid-July, burns all the foliage and more tender stems of the chokeberry[6] and does not injure cranberry vines or berries.
2. A spray of 20 pounds of copper sulfate in 100 gallons of water, applied heavily late in July or early in August, destroys nut grass[7] very effectively. At the same time of year, a stronger solution, 25 pounds in 100 gallons, burns off the tops of *Bidens* and *Aster* and the foliage of wild rose and severely burns barnyard grass[8] and some kinds of *Panicum* and so keeps them from seeding. It is also considerably effective against loosestrife.[9] These sprays do little or no harm to cranberry vines or fruit. Copper sulfate is evidently a very important addition to the list of chemical killers of cranberry bog weeds. It kills some of the same weeds that kerosene kills and at half the cost for materials.
3. A spray of 1½ pounds of sodium arsenate in 100 gallons of water, applied early in August at a rate of 100 to 150 gallons an acre, is a satisfactory treatment for wild bean,[10] triple-awned grass,[11] and partridge pea.[12] It also burns off the foliage of the coarser brambles.[13]
4. A paddle-mix emulsion of kerosene and water, made with Aresklene or Nopco fish-oil soap as the emulsifier, promises to control horsetail[14] as well as

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[6] *Pyrus melanocarpa* Willd.

[7] *Cyperus dentatus* Torr. and *C. strigosus* L.

[8] *Echinochloa.*

[9] *Lysimachia terrestris* B S P.

[10] *Apios tuberosa* Moench.

[11] *Aristida gracilis* Ell.

[12] *Cassia Chamaecrista* L.

[13] *Rubus* spp.

[14] *Equisetum* spp.

kerosene alone, at a third of the cost for materials. It also burns off completely the foliage of hoary alder.[15]

5. A spray of 75 pounds of sodium chloride in 100 gallons of water eliminates fireweed[16] and beggar-ticks.[17]

6. Iron sulfate spread broadcast late in June or very early in July, a ton to an acre, eliminates tearthumb.[18]

Cold Storage of Cranberries. (C. I. Gunness, H. J. Franklin, and C. R. Fellers.) The study of home cold storage of cranberries begun in 1936 was continued, the Department of Agricultural Engineering and the Department of Horticultural Manufactures cooperating with the Cranberry Station. A small insulated 4-room refrigerating plant was equipped at the Cranberry Station and berries were kept in it at 35°, 40°, 45°, and 50° F. Berries were also kept in cellar and other storage for comparison. A detailed report is not yet justified, but it is extremely interesting that it was found that partly ripe cranberries color up very much better at 45° to 50° F. than at temperatures either higher or lower than that.

Late Ripening and Keeping Quality of Cranberries. (H. J. Franklin.) A study of the relationship of the earliness of the ripening of cranberry crops to their relative keeping quality was based on the yearly records of first carlot shipments of the New England Cranberry Sales Co. from 1912 to 1937 inclusive, and the records of Dr. Neil E. Stevens of general cranberry keeping quality in those years. It showed that the crops that ripen late apparently always keep well.

COOPERATIVE CRANBERRY INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station

H. F. Bergman, Senior Pathologist, U. S. D. A., in Charge

Development of Strains of Cranberry Resistant to False Blossom. (H. F. Bergman and W. E. Truran.) Reciprocal crosses were made during the past season between Early Black and the varieties Aviator, Centennial, McFarlin, and Shaw's Success; also between Centennial and McFarlin and between Centennial and Shaw's Success. In addition to these the following crosses were made: Early Black x Paradise Meadow, McFarlin x Aviator, McFarlin x Paradise Meadow, McFarlin x Shaw's Success, Shaw's Success x Aviator, and Shaw's Success x Paradise Meadow. Seeds from these crosses will be planted during January and February. Seedlings from crosses made in 1935 were set out on the bog during the past summer.

During the last week in August some 300-400 clones of wild cranberries were collected in Maine. Several different localities and habitats were represented in these collections. The vines were taken to East Wareham, where they are being stored over winter to be propagated in 1938. Vines collected in Maine in 1931 and 1932 have made slow growth on the bog due to very dry summers since they were set out, but many of them are now beginning to bear fruit. Several of the selected wild vines show very desirable vine and fruit characters under cultivation.

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[15] *Alnus incana* Moench.

[16] *Erechtites hieracifolia* Raf.

[17] *Bidens* spp.

[18] *Polygonum sagittatum* L.

Oxygen Content of Flooding Water in Relation to Injury to Cranberry Vines. (H. F. Bergman and W. E. Truran.) Measurements of the oxygen content of the water and of the light intensity at different depths were made on several bogs which were flooded during late May and early June for insect control. The minimum light intensity necessary to maintain the oxygen content of the water at a level high enough to prevent injury to the buds depends upon a number of interacting factors which vary from bog to bog. On one bog flooded to a depth of 12-16 inches the oxygen content of the water, at 22° C., increased as long as the light intensity at a depth of 12 inches did not fall below 12 percent of the full midday intensity. When the light dropped below 12 percent the oxygen content also decreased. The oxygen content of the water on all bogs examined was sufficiently high to prevent bud injury.

Spraying Experiments. (H. F. Bergman and W. E. Truran.) Preliminary experiments on the control of rose-bloom of cranberry showed that this disease may easily be checked by sprays. Although no spraying was done until the rose-bloom had developed fully, one application of 5-2-50 Bordeaux with rosin fish-oil soap as a spreader and sticker, applied at the rate of about 300 gallons per acre, greatly reduced the infection and two applications entirely eliminated it.

In spraying experiments for the control of fruit rots, Z-O, a copper fungicide of unknown composition, in concentrations of 1-50 or 1½-50, and Cupro K, a form of copper oxychloride, 1½-50, applied at the rate of 250-300 gallons per acre, gave much poorer control of rots than did Bordeaux 5-2-50 applied at the same rate. Bordeaux 5-2-50 with rosin fish-oil soap reduced the amount of rot to one-third to one-half of that of the check plots. Copper hydro 40 at concentrations of 4-50 or 5-50, applied at the rate of 250-300 gallons per acre, compared favorably with Bordeaux in the reduction of rot. On some plots it reduced the rot more than Bordeaux. On other plots on another part of the same bog Bordeaux gave the better control. A copper oxide spray made up with Cuprocide 1½-50, bentonite 2½-50, or Cuprocide 2-50, bentonite 3¾-50, applied at the rate of 250-300 gallons per acre, brought about a greater reduction in rot than did Bordeaux 5-2-50 applied at the same rate.

As Bordeaux with soap does not give a uniform spray deposit on leaves and fruits of the cranberry, various adjuvants in different proportions were added to the Bordeaux to determine whether better spread and adhesiveness could be obtained and the effectiveness of the spray thereby increased. Bordeaux 5-2-50 was used in all tests. To 50 gallons of this was added one of the following materials or combinations: Penetrol 1 quart; Areskap ½, 1, 2, 4, 8, and 16 ounces, respectively; Santomerse 2 and 10 ounces, respectively; bentonite 2½ pounds; bentonite 2½ pounds with 1 pound of rosin fish-oil soap; bentonite 2½ pounds with Areskap 1, 2, and 8 ounces, respectively; bentonite 2½ pounds with Aresket 4 ounces (Areskap, Aresket, and Santomerse are sodium salts of sulfonated diphenyl compounds). Determinations of copper in the spray residues on leaves were made within 1 to 2 days after the vines were sprayed and again shortly before the berries were picked. None of the materials used increased the amount of copper in the spray residue beyond that in the residue of Bordeaux made up with rosin fish-oil soap, although somewhat better distribution of the spray coating was obtained when 4-8 ounces of Areskap were added to 50 gallons of the spray than with the Bordeaux to which rosin fish-oil soap was added. On plots on which poor control of rots was obtained, it was found that the copper content of the spray residue was very low. Otherwise there was no evident relation between the amount of copper in the spray residue and the degree of rot control.

Blueberry Disease Investigations. (H. F. Bergman.) A blighting of flower clusters and new leafy shoots of blueberry caused by *Sclerotinia* was worse in

1937 than for several years previous, but was not sufficiently abundant to be destructive. As the season advanced, leafy shoots ceased to be affected, but the disease continued to affect the flower and fruit clusters up to the time that the fruits ripened, when typical "mummy" berries developed. A hybrid variety not grown commercially was worst affected. The disease also occurred to a considerable extent on Cabot and Pioneer.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Nutritive Value of Chocolate Flavored Milk. (W. S. Mueller and W. S. Ritchie, Department of Chemistry.) Some of the results of this investigation have been published in the *Journal of Dairy Science*, 20 (6): 359-369, 1937.

The results of the previous year on the effect of feeding varying percentages of cocoa to white rats were checked on 16 male rats. At the end of six weeks the average gain of the rats on the various diets was as follows: No cocoa, 60.5 grams; 1 percent cocoa, 60 grams; 2.5 percent cocoa, 55.2 grams; 4 percent cocoa, 47.7 grams. These results confirm the previous findings.

In another experiment Dutch and American process cocoa were compared. Only one level of cocoa, 4 percent on a fluid milk basis, was fed. In addition to minerals and cane sugar, all of the diets contained 2 percent by weight of dried brewers' yeast, and two drops of cod liver oil were added daily to the ration. Twelve males and fifteen females were used in this experiment.

The average gain after six weeks was as follows:

No cocoa (control)	64.5 grams
Dutch process cocoa	65.3 grams
American process cocoa	60.5 grams

The rats receiving the American process cocoa did not do quite so well as those receiving the Dutch process cocoa. However, the most striking result from this experiment was the fact that there was no retardation in growth of the rats on the 4 percent Dutch process cocoa, as in previous experiments. As expected, the consumption of cocoa per day increased slightly when the diet was supplemented with yeast and cod liver oil. Since larger quantities of cocoa reduce the palatability of milk until the zero point is reached, it may be that this explains the observed lack of growth in the earlier experiments, rather than that the cocoa exerts a toxic effect. This phase of the problem is receiving further study.

Urine analysis. In order to secure information on the physiological action of cocoa, urine analyses were made. Samples over a period of 24 hours were collected from 12 animals, four rats on each of the following diets: No cocoa, 4 percent Dutch process cocoa, and 4 percent American process cocoa. The average results for five trials are given in the following table:

Kind of Cocoa	Volume per day c.c.	Specific Gravity	Acidity c.c. .1 NaOH	pH	Uric Acid mg per c.c.
No cocoa (control)	4.6	1.043	2.3	6.72	0.2064
Dutch process cocoa	5.7	1.037	2.6	6.49	0.1913
American process cocoa	5.6	1.034	2.4	6.45	0.2023

In a general way, these results show no marked differences in the urine excreted by rats which received the Dutch and American process cocoas. However, differences were noted when the urine excreted by rats which received cocoa was compared with the urine of rats in the control group. Further trials are necessary before definite conclusions can be drawn.

Fecal pH studies. Fecal pH studies on samples collected from animals receiving no cocoa, 4 percent Dutch process, and 4 percent American process, showed no marked differences when the quinhydrone electrode was used.

Digestion of chocolate-flavored milk in vitro. The purpose of this study is to check, if possible, the results on the animal feeding experiments. Only preliminary experiments were made with whole milk powder plus cane sugar, alone and when supplemented with 4 percent of Dutch process cocoa (on a fluid milk basis). Digestion was carried out with artificial gastric juice, in a rotating machine set in an incubator at 37° C., in order that digestion might go on under conditions somewhat approaching those of the stomach. Samples were removed after five hours and analyzed for soluble nitrogen by the direct micro-Kjeldahl method. Preliminary results show that milk alone gives a greater total rise in soluble nitrogen than does the chocolate milk. However, it was observed in the preliminary work that the micro method was not sensitive enough and it will be replaced by the regular Kjeldahl method in further studies.

This year's work on the nutritive value of chocolate-flavored milk seems to indicate that when cod liver oil and yeast were fed, as good gains were noted in the rats receiving chocolate milk as with the control group receiving whole milk. The same amounts of yeast and cod liver oil were fed to both groups.

Some Factors Affecting the Properties of Whipped Cream. (W. S. Mueller.) Additional factors studied during the past year were the effect of agitating the cream after pasteurization and the effect of oat flour on whipping cream. The same whipping procedure was used in these investigations as was used in the previous studies.

Cream containing 30 percent butterfat was cooled over a surface cooler to 40° F. after pasteurization and then portions were subjected to one-half, one, and two minutes of agitation with the cream whipper. The cream was then aged for 24 hours at 40° F. before whipping. Results seem to indicate that preliminary agitation had no significant effect on maximum stiffness and serum drainage, and slightly decreased the overrun. The sum total of the preliminary and final whipping time was practically equal to the whipping time for the control, which was not agitated before aging. Effect of agitation after pasteurization at temperatures other than 40° F. are being studied.

The addition of 0.5 percent by weight of oat flour to whipping cream (30 percent butterfat) increased the viscosity, decreased whipping time, slightly increased maximum stiffness of the whipped cream, and slightly reduced the serum drainage, but had no significant effect on overrun.

The addition of a skim milk extract of oat flour to whipping cream (30 percent butterfat) had no significant effect on the viscosity of the cream or on the whipping qualities of the cream.

The Effect of Aging Treatments on Gelatin and Other Ice Cream Stabilizers. (W. S. Mueller.) A photo-electric tyndallmeter was developed in the dairy laboratory for studying the effect of aging treatments on the tyndall phenomenon of gelatin-water solutions. A detailed description of this instrument appeared in *Food Research* 2:51-54, 1937.

It was shown that the effect of gelatin in ice cream mixes can be increased by using a higher initial aging temperature. By cooling only to 68° F. after homogenization, and aging at that temperature for several hours, followed by aging at the usual temperature, a more viscous mix results, and the ice cream frozen from this mix showed a higher melting resistance. The gelatin content can be reduced by one-fourth by this method of aging. Gelatin-water solutions aged under comparable conditions after solution at 45° F. exhibited a similar difference in gel strength and basic viscosity. This study was continued by subjecting water solutions of sodium alginate, karaya gum, and oat flour to high initial aging temperature treatment as described for gelatin. These substances, which are used to some extent as stabilizers for ice cream, ices, and sherbets, did not exhibit the differences in gel strength and basic viscosity that were noted with gelatin. Further studies are being made with other stabilizers.

These results indicate that it would be of no advantage to an ice cream manufacturer to use a high initial aging temperature when using stabilizers such as sodium alginate, karaya gum, and oat flour, without gelatin.

Improving the Flavor and Keeping Properties of Milk and Some of Its Products. (W. S. Mueller and M. J. Mack.) It is generally conceded that the butterfat (including fat-like substances) is the major constituent affecting the flavor and keeping properties of milk and its products. A slight oxidative change in the butterfat content of the dairy product will produce flavor defects which are variously described as storage, cappy, cardboard, metallic, oxidized, and old ingredient. Among the many factors that have been mentioned as accelerators in the production of oxidized flavors in milk fat are light, heat, moisture, acidity, enzymes, and metals.

The addition of edible antioxidants to dairy products appears to be a feasible method for preventing or retarding oxidized flavors. The object of this study is to obtain more information on the effect of the following antioxidants on the flavor and keeping quality of dairy products: Carotene, ascorbic acid (Vitamin C), lecithin, cereal flours, and possibly ice cream stabilizers of vegetable origin. Most of the work to date has dealt with the effect of oat flour on the keeping property of ice cream, butter, frozen cream, whipped cream, and whole milk powder.

The use of only 0.25 percent of oat flour in ice cream mix delayed the development of off-flavors during the storage of the resultant ice cream, although 0.5 percent proved more effective. Oat flour also proved to have stabilizing properties. The stabilizing action of this antioxidant increased mix viscosity, improved the body and texture, and increased the melting resistance of the ice cream. When oat flour is added to the mix, a reduction should be made in the amount of gelatin or other stabilizer used if an overstabilized condition is to be avoided. The results indicate that a reduction of at least 25 percent of the gelatin content is desirable when 0.5 percent oat flour is incorporated in the mix. The use of oat flour as an antioxidant in ice cream is described in the October 1937 issue of the *Ice Cream Trade Journal*.

Oat flour, at the rate of one percent of the fat weight of the cream added to cream before pasteurization retarded the oxidative deterioration of butter. Also, the addition of an aqueous extract of this antioxidant to cream prior to pasteurization improved the keeping quality of the butter.

Butter was wrapped in parchment paper treated with oat flour, and stored at temperatures of 38° F. and 0° F. These samples have not been in storage long enough for marked differences to appear.

Cream containing two percent by weight of oat flour, which was added before pasteurization, was frozen and stored at 0° F. A control sample was also placed in storage at the same time. After three months in storage the cream was examined and no marked differences in flavor were noted, except that the cream containing the antioxidant had a very pronounced oat flour flavor, thus showing that too much of the antioxidant had been added.

Two samples of whole milk powder prepared with and without oat flour by a commercial milk plant were examined. The milk powders were dissolved in water so that the total solids content was equal to that of normal fluid milk. The milk powder containing the antioxidant had a better flavor than did the control. This observation will be checked by determining the peroxide value of the fat. The amount of peroxide oxygen present in a fat serves as an excellent criterion of the degree of oxidation of that fat.

The effect of an antioxidant in whipped cream was also studied. Oat flour, 0.5 percent by weight, and also skim milk extract of oat flour were added to whipping cream before pasteurization. No marked differences were noted in the flavor of the whipped cream after one week's storage at approximately 36° F. It should be mentioned that the cream used in this experiment was of exceptionally good quality. The experiment will be repeated using a lower grade of cream and also a higher storage temperature for the whipped cream.

Trials will be made in the near future with other antioxidants of a non-toxic nature.

Sodium Alginate as a Stabilizer for Ice Cream. (M. J. Mack.) Previous studies have shown sodium alginate to be a satisfactory stabilizer for ice cream. Mixes containing the stabilizer were relatively uniform in viscosity, required no aging before freezing, and whipped readily to the desired overrun. The resultant ice cream was smooth in texture and possessed desirable melting characteristics.

This project is being continued with the study of another form of sodium alginate which may prove superior to that previously used.

The Stability of the Fat Emulsion in Cream. (M. J. Mack, in cooperation with Herbert Jenkins, New England Dairies, Inc.) A detailed study was made of the separation of oily droplets of butterfat from cream when used in coffee. This fat separation from cream in coffee is usually referred to as "oiling off". It is considered objectionable by some consumers and many buyers for restaurants and hotels. Therefore the dairyman should handle cream so that the defect will not occur.

The cause of the oily separation is the partial destruction of the normal emulsion of the fat globules in cream. Any factor or factors which will cause fat globules to coalesce may increase the size of some globules to the extent that they will rise to the surface in hot coffee and be readily apparent. The more important factors involved are as follows:

1. The separation of milk partially frozen during delivery will produce a cream capable of oily separation in coffee.

2. Separating temperatures higher than 90° F., excessive agitation of milk while preheating for separation, and the separation of cream higher in butterfat than 45 percent, decrease the stability of the fat emulsion.

3. Prolonged holding of cream at the pasteurization temperature increases the amount of destabilized fat in cream. The partial filling of pasteurization vats causes similar undesirable results. Stainless steel or glass-lined steel vats with slow propellor or paddle agitation and a heating medium of 160° F. produced satisfactory results. However, an increase in the speed of agitation or in the temperature of the heating medium, in these same vats, increased the oiling off tendency. Coil vats, regardless of the temperature of the heating medium, destabilized the fat emulsion. Heating cream to pasteurization temperatures higher than 145° F. increased the amount of oil separation slightly. Whether cream is agitated slowly or not at all during the holding period apparently made no difference, but rapid agitation caused oiling off.

4. Pumping cream from pasteurizer to cooler by proper size centrifugal pumps had no effect on the fat emulsion, while the use of oversize pumps destablized the fat to some extent. Steam piston pumps do not affect the fat emulsion adversely; in fact, with cream which oiled off badly, the piston pumps partially re-emulsified the fat which had separated.

5. Cooling cream in the pasteurizing vat was found to be very undesirable regardless of the type of agitation employed. The final temperature to which cream is cooled over a surface cooler does not affect the fat emulsion so long as freezing to the cooler does not occur. Freezing of cream to the cooler was found to be one of the most serious causes of oiling off of cream in coffee.

6. Aging cream (without agitation) at low temperature caused no change in the stability of the fat emulsion. Shipment at low temperature also had no effect unless the cans were only partially filled, thus allowing for agitation, which proved harmful.

7. Reducing the fat content of pasteurized cream by the addition of milk or skim milk had no effect on the tendency of the cream to oil off.

8. Cream which had been improperly handled, so that droplets of oil would separate from it if used in coffee, was made entirely stable by homogenization at the pasteurization temperature. A pressure of 500 pounds was used. Attempts to re-emulsify the fat by the use of a colloid mill and manually operated emulsor were partially successful.

9. Storage of cream for three days in a household refrigerator did not increase the tendency to oil off when the cream was used in coffee.

A Study of the Changes that Occur in the Storage of Frozen Sweet Cream. (H. G. Lindquist.) The effect of adding sodium alginate (cocoloid) in amounts of .05, .1, and .15 percent to 32 percent cream was studied. Sodium alginate increased the viscosity of the cream before freezing. There was a slight increase in pH, and the frozen cream containing sodium alginate showed less tendency to oil off when thawed than did the frozen pure cream. When thawed, the frozen cream containing sodium alginate whipped up into a firmer whipped cream with less drainage than did the frozen pure cream.

A Study of the Efficiency of Water Heaters, Electric Sterilizers, and Electrically Operated Cooling Tanks. (J. H. Frandsen, H. G. Lindquist, and Myer Glickstein.) Electric water heaters were studied to determine whether they could be used effectively as sterilizers when used to generate steam. In general, they were found satisfactory if utensils were exposed to the steam for four to eight minutes after they had been thoroughly washed. As a rule, the electric sterilizers and steam generators are of simple construction and easy to operate.

The effect of increasing the wattage in the heating element by 500 units does not produce any decided or comparable difference in the destruction of bacteria. Perhaps this is due to the great variation with which the bacteria are rinsed from the cans. However, it took less time to generate steam with the larger heating element.

A Study of the Possibilities of Milk, Cream, and Plastic Cream in the Development of New Products such as Combinations with Honey, Fruits, Cheese, and other Flavors of Various Kinds. (J. H. Frandsen and Myer Glickstein.) A study of the use of plastic cream and cheese in combination with certain fruits and nuts has been made and the work is being continued.

The successful incorporation of sweet fruits, sub-acid fruits, candies, nuts, and certain aromatic ripened cheeses to bases such as plastic cream and cream cheese proved to be popular and lent a variety of appeal to the palate. The proper proportions and methods of handling have been determined and it was found that, although in most instances the combinations were successful, the use of fresh, canned, or frozen strawberries and peaches produced a mild flavor unless reinforced with fruit extract. The chocolate combination was the poorest according to the consumers' comments. Butter pecan proved to be the most popular. Storage of these types of spreads is limited to two weeks at 45°-50° F. The consistency and body of these spreads were good in all cases where drained fruits were used.

Further experiments with new and desirable flavors will be undertaken, and the addition of dried aromatic plants to milk to be made into cheese offers many possibilities.

A Study of the Effect of Organic and Inorganic Iodine on Some of the Milk and Digestive Enzymes. (J. H. Frandsen, W. S. Mueller, and Myer Glickstein.) A previous study on the effect of inorganic iodine on the enzymes revealed the fact that enzymatic activity was inhibited in most cases if sufficient iodine was added to the substrate. In the present study, similar experiments are now being conducted in an endeavor to note the effects of organic iodine on the enzymes as well.

Results up to date show that in concentrations as high as 100 p.p.m. of both types of iodine, the activities of different enzymes are affected differently.

When the substrate is not preserved with toluene, organic iodine stimulates catalase activity more than does inorganic iodine. Both kinds of iodine, however, showed a fairly marked increase in the production of oxygen by catalase over the control series containing no added iodine. In those samples preserved with toluene, there is no difference between the inorganic and organic iodine.

In the case of peroxidase, the control and the inorganic iodine series showed little appreciable differences in their purpurogallin numbers. The organic iodine group, however, showed an increase in peroxidase activity by over five times that of the other two groups.

Over a period of 16 days' incubation there was an increase of .159 percent acidity, in reference to lipolytic activity, for the control group, as compared to .0855 percent and .1000 percent for the inorganic and organic iodine groups respectively.

The results also showed a rather marked stimulation of rennin activity by organic iodine when compared with the group containing no iodine. Inorganic iodine is not quite so effective in stimulating this enzyme as is organic iodine.

In reference to steapsin or pancreatic lipase, the control and organic iodine groups are practically similar in their effects. In the case of inorganic iodine, there was a marked inhibitory effect on this enzyme.

Work is now in progress with the proteolytic enzymes such as pepsin, trypsin, and protease. No results can as yet be given on these enzymes.

DEPARTMENT OF ECONOMICS

Alexander E. Cance in Charge

Recent Changes in Consumer Demand for Milk and Some Factors Affecting it. (David Rozman.) In connection with this project, field work was carried on in Northampton, Holyoke and Pittsfield. In each of these cities information was obtained from individual families representing a cross section of the population, on the consumption of fluid milk at the time of the investigation as well as the trend over a period of several years. An effort was made to determine the effect of important factors on the trend of milk consumption especially as it is influenced by various regulatory measures and retail price policies. A total of 306 family schedules was obtained in Northampton, 751 in Holyoke and 719 in Pittsfield. From the preliminary tabulations so far obtained it appears that the average consumption of milk in these cities varied from 6.45 pints per week per capita in Northampton, to 6.87 in Holyoke and 5.47 in Pittsfield.

The available information points to the fact that a lower rate of consumption in Pittsfield has been partly due to the higher prices for retail milk, while in Holyoke lower prices for delivered milk and the fact that a considerable number of the people bought their milk from the store at lower prices accounted for higher consumption. However the deficiency in fluid milk consumption in Pittsfield was compensated to a certain extent by a greater use of canned milk, as it appears that about one-half of the families included in this survey purchased this product, as compared with only one-fourth in Holyoke.

Land Use Problems in Massachusetts in Relation to the Balanced Program of Land Utilization. (David Rozman.) The work on this project was originally inaugurated in cooperation with the Bureau of Agricultural Economics and the Agricultural Adjustment Administration, and for two consecutive years has been carried out under two projects: A Study of Adjustments in Farming by Regions and Type-of-Farming Areas, from the standpoint of Agricultural Adjustment and Planning, including Soil Conservation; and A Study of Farm Organization and Soil Management Practices in Massachusetts in Relation to Agricultural Conservation and Adjustment, with Special Reference to the Formulation of a Program under the Soil Conservation and Domestic Allotment Act.

In the process of the work it has become apparent that the pattern of land use in Massachusetts is extremely varied and complicated and that a basis for an adequate land program should include the study of other important land uses in Massachusetts, covering recreational, forestry, industrial, part-time farming, and other developments. During the past year it has been possible to make considerable advance in providing an adequate basis for a land use program in cooperation with the State Planning Board and the W. P. A. organization. A complete survey of land resources was carried out covering all the rural areas of the State. The results are being reproduced in a series of maps showing the most important physical characteristics by individual towns.

Five basic maps are being prepared for each town, drawn to the scale of two inches to the mile. The first map shows the existing land use and cover for individual tracts of land, indicating areas devoted to various agricultural uses, types of forests, recreational uses, as well as industrial, commercial, and residential developments. The second map in the field survey indicates the exact location of roads and buildings by their type and condition. A special map is devoted to the character of the soil, classified in several groups on the basis of productivity and adaptability for agriculture, forestry, and other uses. Other information includes the topography of each town by means of contours with 20-foot intervals, and also roads and waterways. With the results of this survey available it will be possible to work out a program for scientific land classification indicating the area especially adapted for agriculture, as well as for forestry, recreational, industrial, and part-time farming development.

DEPARTMENT OF ENTOMOLOGY

A. I. Bourne in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne and W. D. Whitcomb, Waltham.)

Oil Sprays for Dormant Applications. The outstanding features of the winter of 1936-37 were the unusually high temperature and the light snowfall. The high mean temperatures of January and February have only been exceeded three or four times since the weather records were first taken in 1889. The weather during March, however, was somewhat colder than usual and there was very little development of fruit buds, so that by early April the season was approximately normal. The snowfall was light throughout the entire winter and most of it melted soon after it appeared; consequently, by early spring the ground was clear of snow, free from frost, and conditions in the orchards for spraying were the best in years.

During April the normally cool weather was interrupted by occasional very warm days which stimulated rapid development of fruit buds. These warm periods were often followed by sudden drops to comparatively low temperatures. Growers found it difficult to cover their orchards in time, and considerable oil injury to the opening buds occurred as a result of the low temperature immediately following application.

European red mite was so scarce in the college orchard that there was not sufficient material on which to check the efficiency of different oil sprays. Most of the trees showed no infestation at all. One new type of oil, which had just appeared on the market, was tested as to its relative safety on different varieties of fruit trees. This oil spray comprised a mixture of 96 percent petroleum oil and 4 percent phenol derivatives. It contained no emulsifying agent but was prepared for spraying by the addition of a goulac-bentonite emulsifier to the water before the oil was poured into the spray tank. The use of such an oil involved extra steps in preparation. The final spray mixture, however, proved very stable and no injury to buds or retardation in seasonal development was evident.

Substitutes for Lime-sulfur in Summer Sprays for Orchards. These tests were conducted in cooperation with the Departments of Pomology and Botany. Two copper fungicides were used in post-blossom sprays following the standard spray program through the calyx application. One of these was also used throughout the season. Liquid lime-sulfur 2-100 with spray catalizer, 2 pounds in 100 gallons, was used in pre-blossom and calyx sprays, and wettable sulfur thereafter. Spray catalizer is a spreader, sticker, and corrective agent in the lime-sulfur–lead arsenate combination. Tests were continued with diminishing strength lime-sulfur at 1-50 strength in pre-pink, 1-60 in the pink and 1-75 in the calyx, to secure adequate scab control and avoid injury to foliage. A mixture of dry lime-sulfur and 325-mesh sulfur was applied in a complete schedule throughout the season. All of these materials were used in combination with lead arsenate at the strength of 4 pounds per 100 gallons in the calyx, 1st and 2d cover sprays; 3 pounds per 100 gallons in the pre-pink, pink and 3d cover; and 2 pounds per 100 gallons in the 4th cover. They were also compared with the standard spray program recommended for Massachusetts, including liquid lime-sulfur in the pre-blossom and calyx sprays and wettable sulfur thereafter. Because of the prevalence of scab an emergency application of fungicides was made on June 22 between the 2d and 3d cover sprays.

Characteristic spotting and crimping of the leaves followed the application of the copper sprays on all varieties; also considerable russeting of fruit. There was more leaf burn than usual following the standard spray program and very slight difference in visible injury between the modified lime-sulfur programs and the standard. The dry lime-sulfur–sulfur combination caused noticeably more foliage injury, and spray catalizer much less damage than the standard program.

The season was the most difficult one in recent years in which to attempt to control either disease or insect pests. Unfavorable weather frequently interrupted the spray schedule, especially during the critical period before bloom, and lessened the efficiency of the different applications. The relative merits of the different sprays were based on the results on the variety McIntosh as follows:

Material Tested	Percentage of Clean Fruit	Percentage of Fruit Showing Injury from—			
		Scab	Curculio	Codling Moth	Spray Russet
Coposil throughout season	22.6	56.7	29	8.4	100
Coposil 3d and 4th cover sprays	69.8	22	6.6	2.8	15.6
Copper Zeolite 3d and 4th cover sprays	73.1	8.5	16	3.2	19.5
Spray catalizer	58.5	20.9	18	3	4.1
Lime-sulfur modified	57.5	15.7	25.7	4.6	2.1
Dry lime-sulfur and 325-mesh sulfur	42.6	21.6	34.6	7.9	0.6
Standard program	67	2.4	23.4	6	1.7
Check	0.0	92.3	35.1	21	0.0

Sprays to Control White Apple Leafhopper. The infestation by the second generation of the white apple leafhopper in eastern Massachusetts in 1937 was the most severe in recent years. Examinations of untreated trees in 5 different orchards showed an average of 5 to 20 leafhoppers per leaf during the first week in September.

Orchard applications of pyrethrum dust 30-70 were generally unsatisfactory. In most cases there was a good knockdown of leafhoppers but a rather rapid recovery and reinfestation. A leaf count in one orchard showed a reduction from 8 leafhoppers per leaf to 2, and in several instances a complete cleanup resulted on those branches receiving a direct blast from the duster, but the insects were affected but little where exposed only to dust drift. Applications from the two sides of the tree were more effective than from one side. Favored by hot weather and timely treatments, nicotine–lime dust (2.4 percent nicotine) gave very good control in one orchard and provided excellent protection to the foliage.

A check on the effectiveness of spray materials applied by the orchardist was very confusing and discouraging, apparently due to an uneven application of the spray. For example, an examination of 100 leaves showed an average of 1.04 leafhoppers per leaf, but 60 leaves had 15 hoppers or an average of 0.4 per leaf while the other 40 leaves had 89 hoppers or 2.2 per leaf. In another case, 100 leaves averaged 0.55 per leaf where 60 leaves had no hoppers and 40 leaves had 55 hoppers.

Under these conditions, counts indicated a good reduction in leafhoppers from nicotine and pyrethrum materials used with soap. When counts were made 5 and 8 days after spraying, it appeared that the number of hoppers decreased with time where nicotine was used, but that the number of hoppers increased with time where pyrethrum was used.

In laboratory experiments with pyrethrum and cube dust and with pyrethrum and nicotine sprays, all leafhoppers were killed in 24 hours. When the leaves were dusted with pyrethrum before the hoppers were confined, all of the insects were also killed in 24 hours. Experiments with these materials at constant temperatures of 60°, 70°, and 80° F. showed a slight but not consistent increase in effectiveness at 80°.

Summer Sprays for European Red Mite. Laboratory and orchard trials, in eastern Massachusetts, of some of the newer insecticides, especially those which might control both the white apple leafhopper and the European red mite, indicated that the nicotine and pyrethrum materials were ineffective against the red mite, but that the cyclohexylamine derivative gave good control at dilutions of 1-400 and 1-200.

Control of the Squash Vine Borer. The average field infestation by the squash vine borer in Hubbard squash at Waltham in 1937 was 3.68 borers per vine, which is three times as heavy as last year. The borer moths were late in appearing and the first treatment was not applied until July 9, followed by 3 additional applications at weekly intervals.

The liquid sprays were consistently superior to the dusts although the cube–clay dust containing 0.6 percent rotenone was nearly as effective. As in other years, the spray consisting of nicotine sulfate 1-500 plus summer oil emulsion 1-100 was the most effective treatment and reduced the borer injury 88.59 percent. The wettable cube spray using 4 pounds in 100 gallons of water showed a reduction of 81.53 percent, and being less expensive would seem more practical. Contrary to the results in 1936, the pyrethrum–clay dust containing 30 percent pyrethrum powder was ineffective.

Treatment	Number of Plants	Average Number of Borer Tunnels per Vine	Percentage Reduction over the Check
Check	25	3.68	
Nicotine sulfate 1-500+Oil emulsion 1-100	19	0.42	88.59
Wettable cube spray, 4 lb. in 100	28	0.68	81.53
Nicotine sulfate 1-250	22	0.77	79.08
Cube — clay dust, 0.6 percent rotenone	25	0.84	77.81
*Derris — clay dust, 0.6 percent rotenone	27	1.48	59.79
Pyrethrum — clay dust, 30 percent pyrethrum	29	2.06	44.03

*1936 Derris powder; others, 1937 powders.

Control of Striped Cucumber Beetle on Melons. Striped cucumber beetles were normally abundant in 1937 and killed or damaged seedling melons, cucumbers, and squash which were unprotected. On cantaloupes at Waltham, a part of which were transplanted and a part seeded on June 7, it was necessary to apply insecticides 5 times beginning June 10 and ending July 10. Although these applications were made at approximately weekly intervals, no definite period for treatments could be determined and the plants were sprayed and dusted whenever the abundance of the beetles warranted it. During this period several of the untreated seedlings were killed.

The effectiveness of the field treatments was determined by counts of the number of beetles present on the plants at different periods. A spray of wettable cube powder containing 3.65 percent rotenone and used at the rate of 4 pounds in 100 gallons of water reduced the number of beetles 90 percent, compared to the untreated plants, and was the most effective treatment. Cube-clay dust containing

0.6 percent rotenone ranked next in effectiveness with an 85 percent reduction in beetle population. Calcium arsenate–monohydrated copper sulfate–lime dust 10-20-70, and copper oxychloride–clay dust 1-14 (Dupont "A") were nearly as effective but caused slight to moderate burning of the cantaloupe foliage. Cryolite–clay dust 20-80 (Nat. Sulfur Company) and Cryolite Spray (Nat. Sulfur Co.) 4 pounds in 100 gallons gave 74 and 73 percent control, but the spray also caused some plant injury. Pyrethrum–clay dust 30-70 and tetra methyl thiuram disulfide (Dupont) 1 pound in 100 gallons, as a repellent, were the least effective treatments. However, the latter material seemed to protect the plants from serious injury in spite of a large number of beetles present.

Yield records corresponded with the striped beetle control, and the plants treated with cube–clay dust yielded 2.03 harvested fruits per vine compared to 1.35 fruits on the untreated vines. Based on yield, pyrethrum–clay dust, thiuram disulfide spray, and copper–calcium arsenate–lime dust were good, while the copper oxychloride dust was not significantly better than no treatment.

Control of Cabbage Maggot with Mercury Compounds. In 1937 the infestation by the cabbage maggot at Waltham was the most severe in ten years. Only 1 percent of the untreated cabbage plants produced a salable head and 95 percent of them were killed or severely injured. The roots of most of the untreated plants and those having ineffective treatments were attacked by 30 to 40 maggots, and only an abundance of rain which stimulated the growth of secondary roots above the maggot injury prevented a total loss of these plants.

The first eggs were found on May 7, this being the seventh consecutive year when eggs were first found between May 6 and 10 at Waltham.

Corrosive sublimate, 1 ounce in 10 gallons of water, was applied on May 8, 16, and 22, and continued to give good protection. Two applications of this material on May 8 and 16 gave 98 percent commercial control and yielded 82 percent large and medium heads. A single treatment on May 16 was more effective than one application on the other dates and gave 80 percent commercial protection with 90 percent satisfactory heads.

When pure calomel was dusted on the roots at the time of transplanting, 92 percent commercial protection was obtained and the yield was high. Calomel mixed 1 — 1 and 1 — 3 with clay gave less actual control of the maggot but provided sufficient protection to produce over 90 percent satisfactory heads. Calomel and clay 1 — 9 gave only 54 percent protection, indicating insufficient toxic action.

When the roots of cabbage were dipped at transplanting in a suspension of calomel and various adhesive materials, the protection provided by this coating was inadequate. For this purpose, calomel was used at the rate of 16 grams and 4.8 grams in a gallon of water. It was apparent that the amount of calomel was insufficient rather than that the method of application was faulty. Among the adhesive materials, laundry starch (1¾ ounces per gallon) and a synthetic wax soluble in cold water (1¼ ounces per gallon) were the most satisfactory, while solutions of liquid rubber, gum arabic, and locust bean gum were less effective. When Semesan (10 grams per gallon) was substituted for the calomel, the plants were killed or severely injured, and corrosive sublimate at the rate of 1 ounce in 10 gallons of water combined with the adhesive materials was ineffective.

Results of these and previous experiments indicate that a thorough dusting of the roots of cabbage plants with calomel powder at the time of transplanting gives safe and effective control of the cabbage maggot and can be recommended.

The cabbage maggot was also a serious pest of radishes at Waltham in 1937. Since the insect attacks the edible part of the radish, injury to this crop is more destructive than injury to cabbage.

Plantings at different periods showed great variation in the natural field infestation, the earliest planting being almost a total loss where no treatment was made.

Date Seed Sown	Date Radishes Examined	Percentage of Radishes Not Infested	Percentage of Radishes Moderately or Severely Damaged
May 4	June 4	5	92
May 17	June 16	41	41
June 16	July 15	20	63

Treatments with calomel gave some protection but were less effective than on cabbage and generally not commercially practical as applied. Seed treatments with calomel reduced the infestation 20 to 30 percent but permitted moderate or severe damage to 30 to 70 percent of the radishes. Two or three applications of calomel spray (1 ounce in 10 gallons of water) at weekly intervals beginning when eggs were first found reduced severe damage about 45 percent in the May 4 planting, but were less effective on later plantings. Due to burning and stunting of the plants, corrosive sublimate solution 1-1280 cannot be used safely on radishes.

Control of Onion Thrips. (A. I. Bourne.) At the outset of the growing season weather conditions were very favorable for a rapid growth of the onion plants and at the same time served to retard the development and spread of thrips. This was borne out by the excellent appearance of the onion fields throughout the entire Valley up to the last of June and by the fact that at that time there were practically no thrips in evidence. On the college plots, counts made on June 24 showed most of the plants still uninfested, and comparatively few with one or two thrips per plant. Unusually high temperature and an excess of rainfall during May and June were the chief contributing factors to bring about such favorable conditions.

The early half of July, however, was characterized by extremely hot weather and almost no rain. In the 5-day period from July 7 to 11, the maximum daily temperature was 90° F. or above and reached 96° on the 8th. No rainfall occurred during this period. More ideal conditions for the development of blast could hardly have been produced artificially. Thrips multiplied rapidly during this time and developed the heaviest infestation in recent years. Blast, however, overshadowed all other pests. This began to appear by July 12, within ten days had spread throughout the entire Valley, and by the end of the month plants in many fields had broken down and were dead.

In the experimental plots the thrips infestation was insignificant until early July. On July 6 it averaged 22 thrips per plant. It increased to 40 thrips per plant by July 13 and by July 19 reached 45 which represented an average of less than 3 thrips per linear inch of plant. By July 26, however, the response of the thrips to the excessively hot weather of July 7 to 11 produced an average of 138 thrips per plant. By that time many plants were killed by blast and by August 3 practically all of the plants were dead.

The intervention of blast caused such a migration of thrips from dying plants to those which were slower to succumb that no authentic data could be secured relative to thrips-resistant varieties, although up to the time blast became prevalent both the Valencia and Riverside varieties showed less than one half the infestation of Danvers and were making more rapid growth. Blast appeared on these varieties as soon as on Danvers but their vigorous growth resisted its effects, and as late as August 10 some plants were still alive when all the Danvers were dead.

Blast appeared so early and spread so rapidly through the experimental plots that there was no opportunity to study the effects of contact sprays upon either the insects or the plants.

There was no evidence of the fungus disease of thrips which for several years was very effective in reducing the numbers of the insects. By the time this disease would have normally appeared, there were few, if any, onion plants which had not succumbed to blast

The Spray Residue Problem. (A. I. Bourne.) Although no further reductions in the limit of tolerance on lead residues were made for the shipping season of 1937, growers found the problem of residue prevention complicated by weather conditions.

During the early season the spray program was often interrupted by frequent rains, and proper timing of applications was practically impossible. Scab control proved to be especially difficult and necessitated the use of emergency sprays. Considerable burning of foliage and russeting of fruit resulted from the frequent heavy spraying to control this disease.

Work of previous seasons has shown that unless weather conditions are very favorable, any spray after the 2d cover spray might build up excessive residue. The emergency scab spray of late June increased this danger. The rainfall between this emergency spray and the 3d cover spray and between the 3d and 4th cover sprays was not sufficient to allow the normal removal of the residue. These successive applications, therefore, built up formidable amounts of spray deposit which the three heavy storms of August removed partially but not sufficiently to eliminate the danger of excessive residue. As a result in many orchards the fruit showed excessive amounts of residue at harvest.

A study was made of phenothiazine as a possible substitute for lead arsenate. Both these materials were used in the 4 cover sprays in a block which had received the standard spray program up to that time. The same wettable sulfur fungicide was used with both materials. No spray injury to foliage or fruit followed the use of either material. The difference in control of insect pests between the two materials was slight but in all cases in favor of lead arsenate as shown in the following table.

Material	Percentage of Clean Fruit	Percentage of Fruit Showing Injury from—		
		Curculio	Codling Moth	Minor Insects
Phenothiazine	71.6	20.1	4.1	3
Lead arsenate	77.9	17.8	2.9	1.1

The chief drawbacks to the use of phenothiazine in its present form appear to be inferior suspension qualities and lack of adhesiveness.

The codling moth problem is the one which in most cases leads the fruit grower into difficulties from excessive spray residue on harvested fruit. In Massachusetts much of the damage is due to late season "stings" or shallow pits caused by young 2d brood larvae in August and September. Arsenical sprays at that season build up an excess of spray residue, and to remove it involves the washing of fruit; contact sprays require frequent applications and are expensive.

A study was made of possible measures to supplement the present spray program, and of these the use of chemically treated codling moth bands seemed the most promising. These were used in an orchard where it was estimated that from 75 to 80 percent of the 1936 crop showed codling moth damage. The bands were placed on the trees about June 15 and were examined October 21, after the crop was harvested. In late spring, in preparation for banding, the trunks and main branches of the trees in the test blocks were thoroughly scraped to remove loose bark. At that time many of the trees yielded 80 or more overwintering codling moth larvae. When the bands were examined in the fall, a total of 4,078 larvae was collected. This is an average of 16.4 larvae per band. The greatest number taken from one band was 84. Less than a dozen of the trees failed to show any larvae in the bands and these were trees without a crop.

It is generally recognized that the benefits from treated bands are not realized in full until the season following their application. In this orchard, however, there was a material reduction in the number of stings in the harvested fruit. The larvae destroyed by these bands represent a potential population in 1938 of more than 100,000 codling moth larvae figured on the basis of approximately 40 eggs per female. It has been estimated that the use of codling moth bands in an orchard with heavy infestation is equivalent to at least one extra spray, and the cost is only a fraction of that of the spray application.

Apple Maggot Control. (A. I. Bourne and W. D. Whitcomb.) Apple maggot was of comparatively minor importance in 1937. In the well-sprayed commercial orchards there was practically no injury, and even in the smaller home orchards less damage than usual was noted. The insect has receded from the front rank of orchard pests in the last few years. This decline in numbers is due in large measure to timely spraying, more attention to orchard environment, and concerted action on the part of the growers.

Date of Emergence of Apple Maggot Flies, Waltham

	In Sun		In Shade	
	Cultivated	Sod	Cultivated	Sod
Light Soil				
1st fly	June 28	June 30	July 2	July 11
25% flies	July 15	July 10	July 15	July 20
50% flies	July 19	July 15	July 18	July 23
75% flies	July 21	July 19	July 22	July 26
Heavy Soil				
1st fly	June 29	July 10	June 28	July 10
25% flies	July 12	July 16	July 18	July 17
50% flies	July 19	July 20	July 23	July 19
75% flies	July 26	July 25	July 27	July 27

The percentage of apple maggots which transformed to flies in 1937 (21.37) was the smallest since these records have been taken, and a decrease in the winter survival was indicated for the fourth consecutive year. In spite of this decrease, the influence of soil and atmospheric conditions was consistent with previous records and the greatest emergence was found in the cages having cultivation, light soil, and sun compared to sod, heavy soil, and shade. The first flies appeared in the cages located in the sun, and sod was the most important factor in delaying emergence. The influence of light and heavy soil was less significant than in other years.

Although the season of 1937 was generally late, the time of emergence of apple maggot flies in the cages corresponded more closely with that of 1936 than with that of 1935.

Introduction of Parasites of Oriental Fruit Moth in Peach Orchards. (A. I. Bourne.) Through a cooperative agreement with the Entomology Department of the Connecticut Agricultural Experiment Station, larval parasites of the oriental fruit moth were available for commercial peach orchards. More than 11,000 specimens of *Macrocentrus ancylivorus* were liberated in late June and early July in 36 peach orchards in 7 counties of the State.

Although the very mild winter of 1936-37 was a favorable one for the hibernation of insects, early inspection of peach orchards revealed a very light twig infestation and also indicated practically no survival of parasites from liberations 3 years previous. Late-summer twig collections showed that the fruit moth had built up a heavy infestation, and considerable damage to midseason and late varieties was found in many orchards. One of the orchards in which twig infestation was heaviest and in which the most damage was found in fruit at harvest was located alongside a large planting of quinces. While injury to the peach crop was extensive, the quince crop was ruined. This further confirmed the belief that quinces are highly flavored by oriental fruit moth and constitute a serious threat to any peaches grown in the immediate vicinity.

Potato Spraying Experiments. (A. I. Bourne.) Flea beetles appeared early and were unusually abundant throughout most of the season over the entire State. Even in well-sprayed fields, they proved difficult to control.

Leafhoppers appeared late in the summer and were not abundant enough to cause any damage. Potato aphids during the hot, dry weather in July threatened serious outbreaks, but timely applications of nicotine checked the pest so successfully that no serious injury was caused even in fields of early varieties such as Irish Cobbler.

In the experimental plots, different insecticides were tested on the standard late-season variety, Green Mountain. Twelve applications of Bordeaux mixture were made between June 10 and August 27. Two rotenone compounds, nicotine tannate, a pyrethrum extract, and calcium arsenate were tested in combination with 5-5-50 and 5-3-50 Bordeaux mixture in the applications from July 9 to August 12. The ranking of the different materials on the basis of flea beetle control was as follows:

With 5-5-50 Bordeaux		With 5-3-50 Bordeaux	
Material	Average Number of Punctures per Leaf Cluster	Material	Average Number of Punctures per Leaf Cluster
Cubor (rotenone)	306	Derris	192
Derris (rotenone)	326	Cubor	231
Calcium arsenate	341	Nicotine tannate	302
Nicotine tannate	433	DX	333
Check (Bordeaux only)	488	Calcium arsenate	334
DX (pyrethrum)	520	Check (Bordeaux only)	355

In both combinations the rotenones were about equally effective and decidedly ahead of all other treatments. Both were much more effective in the low-calcium Bordeaux. Calcium arsenate gave equally good protection in both combinations. Nicotine tannate showed to better advantage with 5-3-50 Bordeaux, and the effectiveness of DX, the pyrethrum extract, was greatly increased in this combination. The fact that all the materials gave better control with the 5-3-50 Bordeaux would indicate that their action may be somewhat inhibited by the excess lime of the 5-5-50 combination.

Very general and often severe burning of foliage resulted from the July sprays, many of which were applied at extremely high temperatures. While these frequent applications were unavoidable because of the prevalence of flea beetles, the injury seriously checked the growth of the plants and the set of the tubers. In many cases the plants never fully recovered from this setback so that, on the whole, the yields were comparatively light, as shown in the following table.

Material	With 5-5-50 Bordeaux Yield per Acre Bushels	Percentage of Crop Grade 1	Percentage of Crop Grade 2	With 5-3-50 Bordeaux Yield per Acre Bushels	Percentage of Crop Grade 1	Percentage of Crop Grade 2
Check (Bordeaux only)	261.7	75	11.5	257.5	67	18.5
Calcium arsenate	396.6	83	8.6	270.8	77.5	10.5
Derris (rotenone)	321.7	82.3	9.1	302.5	82.6	8
Cubor (rotenone)	267.5	71.6	13.1	253.4	71.7	15.7
Nicotine tannate	264.1	84.5	6.6	293.4	82.7	7.3
DX (pyrethrum)	245.9	79.3	9.8	270.8	77.8	11

All of the materials gave higher yields when combined with 5-5-50 Bordeaux except nicotine tannate and DX. The yield in the plots of these last two materials reflected the improved control of flea beetles which they furnished when combined with 5-3-50 Bordeaux.

Spray injury was very severe on the plots sprayed with 5-3-50 Bordeaux. This undoubtedly explains the reduced yield.

Two commercial brands of copper sprays for potatoes were compared with the two strengths of Bordeaux mixture. Since many growers have expressed the belief that lime alone would give sufficient protection against blight and insects, it was applied to one plot. The comparative yield following these treatments is as follows:

Material	Yield per Acre Bushels	Percentage of Crop Grade 1	Percentage of Crop Grade 2
Bordeaux 5-5-50	344.3	79.8	7.8
Bordeaux 5-3-50	308.8	76.5	11.9
Copper hydro (Chipman Chemical Co.)	306.6	79.6	11.1
Basic copper sulfate+lime (Sherwin-Williams Co.)	300.7	78.7	12.2
Lime alone	263.2	67.6	18.4

When the potatoes were dug, nearly 1 percent of the crop in the lime plot showed the presence of rot. Sample hills examined earlier in the season showed a much higher proportion of rotten tubers, which led to the belief that many diseased tubers had completely disintegrated by time of digging and that the difference in yield between this plot and the others would more accurately indicate the actual loss due to disease.

The comparative yield in the other plots follows very closely observations made through the season on the relative amount of leaf burn. Considerable injury was noted on the plants sprayed with 5-3-50 Bordeaux and the two commercial sprays. The increased yield in the 5-5-50 Bordeaux plot reflected the superior condition of those plants and their longer period of growth.

Insecticides for the Control of European Corn Borer. (A. I. Bourne.) The studies carried out in 1937 in cooperation with the Federal European Corn Borer Laboratories, included field experiments in Hampden County with dual-fixed nicotine, a newly developed nicotine tannate-bentonite dust, and continued tests with derris and nicotine tannate sprays on two farms in Worcester County. Both sprays and dust were applied as nearly at 5-day intervals as weather would permit, beginning with the first appearance of the young borers in the field. In every case the earliest maturing variety of sweet corn grown on the farm was used in the tests.

Between June 10 and July 5, the period during which applications were made, rain fell on 13 out of the 26 days, and the total precipitation recorded was 4.1 inches. The season was decidedly unfavorable for both sprays and dusts. The frequent rains interrupted the 5-day schedule and often occurred soon after the materials were applied. At least twice it was necessary to make a reapplication following the rain so that 5 applications of sprays and 6 of the dust were made.

There was considerable difference in the infestation on the three farms. In the plot dusted with dual-fixed nicotine, 6 percent of the treated plants and 36 percent of the checks showed stalk infestation. In the derris plot, 5 percent of the sprayed and 12 percent of the checks were damaged by borers. In the treated plots the infested stalks were not often seriously damaged and for the most part they contained only 1 or 2 small, young stage larvae, whereas in the checks the stalks were badly riddled, often contained from 5 to 8 mature borers, and in many cases had broken down before the ears had fully matured. The loss of vitality to the plants caused by even a light or moderate infestation is clearly reflected in the yield records as shown by the following table.

Material	Percentage of Infestation	Increase of Treated over Untreated Plots	
		Increase in Total Ears per Acre	Increase in Uninfested Ears per Acre
Dual-fixed nicotine (dust)........	30	225	1562
Derris (spray).................	5	1692	2052

In every case the treated plots showed an increased total yield over the checks. On the basis of uninfested ears, the difference was even more pronounced. Even in the case of a comparatively light infestation as in the derris plots, an advantage of more than 2,000 ears per acre represented a considerable profit to the grower.

A more significant index of the value of the treatments is the relative proportion of Grade 1 corn harvested from the experimental plots as shown in the following table.

Material	Percentage of Total Yield			
	Uninfested		Grade 1 ears	
	Dusted Plots	Check Plots	Dusted Plots	Check Plots
Dual-fixed nicotine......	92.8	70	76	48
Nicotine tannate........	97.6	94.4	72	60
Derris.................	98.3	94.9	88	81

The field containing the derris plots was heavily fertilized. The corn made excessive stalk growth and many of the ears did not fully develop and were graded as culls. Since the total yield in this field, however, was at the rate of 24,000 ears per acre, even the small difference of 7 percent represented an increase of 1,680 ears.

Since the growers could guarantee borer-free ears, they found a steady demand for their corn and disposed of the crop at a premium. So few of the ears in the treated plots were infested that the growers were able to eliminate the expense of time and labor ordinarily necessary to examine each ear for borers, thus making a material reduction in their marketing costs.

Insects Concerned in the Dispersal of Dutch Elm Disease. (W. B. Becker.) Research work on the biology of the native elm bark beetle, *Hylurgopinus rufipes* Eich., was continued. Freshly cut American elm logs in which eggs were laid in the fall of 1936 and in which the insects passed the winter as larvae were again attacked by new adults in the spring of 1937 for oviposition purposes. Some slight emergence began from these logs early in July and kept up at a very low rate until early in August when the daily emergence increased considerably. At that same time emergence started from logs which had been cut in the early spring of 1937 and were attacked for oviposition purposes for the first time when the above-mentioned logs were attacked for the second time. Emergence continued until late in November when occasional live, newly emerged adults were found in the outdoor cages.

The results of scouting work carried on in 1935, 1936, and 1937 to determine the distribution of elm bark beetles in Massachusetts show that *Scolytus multistriatus* Marsh., the smaller European elm bark beetle, is distributed over a wide area in eastern Massachusetts, and is also found in southwestern Massachusetts; Egremont, Great Barrington, New Marlborough. The identity of the finding previously reported in Westfield, based on the occurrence of two empty brood galleries in an American elm, typical of those of *Scolytus multistriatus*, is now considered uncertain, due to the fact that Westfield is approximately twenty-five miles distant from known limits of the infestation centering at New York City; intensive scouting in the vicinity since then has failed to reveal the presence of the beetles; and detailed study made by this office of the types of brood galleries dug by *Hylurgopinus rufipes* shows that occasionally they construct a single unbranched egg gallery parallel to the grain of the inner bark such as *Scolytus multistriatus* digs instead of the two-branched, more or less transverse egg gallery usually constructed. Until further scouting reveals the actual presence of the *Scolytus multistriatus* beetles in Westfield, this office will consider the previous report uncertain. Adult beetles were collected in all the other towns mentioned. Eastern Massachusetts: Merrimac, Haverhill, Methuen, Tyngsborough, Tewksbury, Andover, North Andover, Boxford, Georgetown, Topsfield, Wenham, Beverly, Danvers, Billerica, Reading, Woburn, Stoneham, Saugus, Revere, Winthrop, Lexington, Sudbury, Weston, Waltham, Belmont, Newton, Brookline, Boston, Wellesley, Natick, Dover, Westwood, Walpole, Canton, Easton, Abington, Rockland, Brockton, Marshfield, Bridgewater, East Bridgewater, Halifax, and Plymouth. *Hylurgopinus rufipes* was found in every section of the State scouted. The only sections not scouted were Cape Cod and the islands off the coast.

A bulletin of a popular nature dealing with the Dutch elm disease and its insect vectors was prepared in conjunction with Doctor M. A. McKenzie of the Botany Department.

Other Elm-Boring Insects. Studies on the habits of two elm-boring insects, *Saperda tridentata* and *Magdalis* sp., were continued. In one cage experiment with *S. tridentata* the adult beetles confined their feeding to the leaves and the current season's twig growth. In some indoor experiments, adult Saperdas which emerged in late winter, when given leafless winter twigs to feed on, attacked only the twig growth of the previous season.

Insect Pests of Shade and Ornamental Trees. A detailed survey was made of the insect pests of the shade and ornamental trees on the campus as a basis for the development of a seasonal spray program.

Fifty-six species of insect pests of various shade and ornamental trees and in addition six types of insect pests of house timbers were sent to the laboratory for identification and information on control.

Apple Leaf-Curling Midge. (W. D. Whitcomb, Waltham.) The apple leaf-curling midge (*Dasyneura mali* Kieffer) was normally abundant in the infested area. In one of the oldest infested orchards, however, the first generation was apparently less abundant than previously, but with the development of the following generations the infestation was equal to that in other years.

In Westford, the activity of this insect began about a week later than in 1936, the first eggs being found May 25, and the first appreciable number of mature maggots was collected under bands on June 22. Eggs of the second generation were abundant from July 2 to 15, and mature maggots were leaving the rolled leaves from July 27 to August 10 A distinct third generation developed on young trees from eggs laid August 20 to 25 and mature maggots were plentiful September 7 to 14. It is now definitely established that a third generation of this midge develops in a normal season and that it can become very abundant on young trees or wherever new growth is available.

No new infestations outside the known infested area were discovered.

Natural enemies, especially *Triphleps insidiosa* Say, were slightly more abundant and active than in other years but failed to cause any noticeable reduction of infested tips.

Control studies were conducted on small trees partly interplanted among old trees and partly in separate blocks. The susceptibility of the different varieties in this orchard was determined by counting the maggots in the rolled leaves of 10 typical infested tips on June 12. The result is as follows:

Variety	Number of Leaves	Number of Maggots	Average Number of Maggots Per Leaf
Baldwin	36	2503	69.5
McIntosh	45	2352	52.2
Starking	45	2048	45.5
Golden Delicious	39	1094	28.0

Experimental sprays were applied 5 times (May 25, 28, June 1, 4, 8) during the oviposition period of the first generation, and again 5 times (July 6, 9, 13, 16, 20) during the corresponding period of the second generation. Although some trees received sprays at both periods, no trees received the same spray materials at both periods. Records were taken by counting the number of infested tips and the degree of injury on each sprayed tree and the number on the nearest unsprayed tree of the same variety and corresponding size.

In general, the protection resulting from spraying was disappointing and from 25 to 60 percent of the tips were infested on the sprayed trees, although only about 10 percent of the tips were moderately or severely infested. Less control was obtained on Starking trees than on McIntosh, Richared, or Golden Delicious. Spraying for control of the first generation reduced the infested tips by 46 to 12 percent. Wettable cube powder containing 3.65 percent rotenone, used at the rate of 6 pounds in 100 gallons, with the addition of 3 pounds of water soluble diglycol stearate wax as a spreader and sticker, applied to McIntosh and Richared 3-year-old trees was the most effective treatment. Nicotine sulfate and molasses, nicotine sulfate with fish oil soap and karaya gum, and a nicotine bentonite wettable powder with a commercial spreader called Ultrawet gave moderate control. Summer oil diluted to 1 percent plus fish oil soap failed completely.

In the second generation experiments, nicotine sulfate 1-800 plus molasses 3 percent was the most effective, and reduced the infestation 48 percent on Golden Delicious. The cube–wax mixture was again good and averaged the best for both series. When nicotine sulfate 1-800 was added to the summer oil–fish oil soap mixture which had failed previously, the control became good although the test was inconclusive because of poor growth on the trees.

A count of the maggots in 10 typical rolled leaves on sprayed trees during the larval period of the second generation showed that the number was reduced in proportion to the effectiveness of the spray in preventing infestation.

Although valuable information regarding the effectiveness of insecticides has been obtained, the only logical conclusion that can be drawn from this work is that spraying alone is not a practical means of combating the apple leaf-curling midge.

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) In 1937 the emergence of plum curculio beetles from hibernation was later than normal and only 2 percent of them were in the trees when the calyx spray was applied to Gravenstein and McIntosh on May 19. By May 24, when Baldwin and Wealthy received the calyx spray, the number of beetles in the trees had increased to 11 percent, and jumped to 32 percent on May 29.

Due to the acute scab situation at that time, an early calyx application was advisable. On McIntosh, lead aresenate could have been safely omitted from the calyx spray but on the more rapidly growing varieties such as Gravenstein, Duchess, Transparent, and Baldwin, it was necessary for the best curculio control.

The critical period in curculio activity extended from May 25 to June 2 with the maximum injury occurring from May 30 to June 1.

In the experimental orchard, which was heavily infested with curculio, studies were begun to determine whether the size of apples during the critical period influenced the control by spraying. Gravenstein apples sprayed with lead arsenate at the rate of 4 pounds in 100 gallons on May 25, when the average diameter of the fruit was 5.04 sixteenths of an inch, had 54.24 percent of the fruit stung. McIntosh which measured 3.94 sixteenths of an inch in diameter when sprayed on May 30 had only 16.14 percent of the fruit stung. Wealthy and Baldwin apples measuring 4.20 and 4.26 sixteenths of an inch when sprayed on May 30 and May 28 showed 18.83 percent and 16.38 percent stung fruit respectively. These preliminary experiments showed that the apples (Gravenstein) which measured approximately 5/16 inch in diameter when sprayed suffered about three times as much curculio injury as those apples (Baldwin, Wealthy, McIntosh) which were approximately 4/16 inch in diameter when sprayed.

Biology and Control of Carrot Rust Fly. (W. D. Whitcomb, Waltham.) The field infestation by the carrot rust fly was moderately light at Waltham in 1937, and the untreated carrots showed 14 percent commercial injury by the first generation. Some injury to celery was reported by market gardeners but this pest was not one of major importance this season.

Treatment of the seed at planting with pure calomel powder gave 99 percent protection, again demonstrating that this is a practical treatment for early carrots exposed to a light infestation. When the calomel was mixed with equal parts of clay as a seed treatment, 4 percent of the carrots were commercially injured; but when the seed was treated with a 1-3 mixture of calomel and clay the carrots showed as much injury as the untreated planting. The addition of powdered gum to the calomel failed to increase the adhesion of the calomel to the seed and gave unsatisfactory results.

Four applications (June 5, 12, 19, and 26) of cube–clay dust to carrots from seed sown May 4 gave complete protection from this insect, and can be recommended.

Adaptability of Cryptolaemus to Control of Mealybugs in the Greenhouse. (W. D. Whitcomb and William Garland, Waltham.) Studies of the development and activity of *Cryptolaemus montrouzieri* at controlled constant temperatures of 60°, 70°, and 80° F. were continued. In the 1937 studies this insect was stimulated at 80° considerably more than in previous observations, although the results again indicated that 80° is slightly excessive and that 70° is nearer the optimum.

Temperature	Average Number of Days Beetles Lived	Average Number of Eggs per Female Beetle	Average Number of Days for Incubation of Eggs	Percentage of Larvae Hatched	Average Larval Growth in Days	Average Number of Mealybug Eggs Eaten by Larvae	
						During Life	Per Day
60° F.	60	50.5	15.0	30.5	*99	1338	14.85
70° F.	65	97.0	8.7	50.7	43.9	1279.8	29.2
80° F.	90	182.0	6.01	38.0	32.3	1217.4	37.6

*Only 1 larva completed growth at 60° F.

Oviposition approximately doubled with each increase of 10° in temperature, and the number of days required for larvae to hatch from eggs was 2½ times as many at 60° as at 80° F. Although the percentage of eggs from which larvae hatched in these studies was low, it was significantly higher at 70° than at either 80° or 60°. At 60° only 1 larva completed development and, therefore, the results at this temperature should not be considered representative. At 80° the average larva ate 1217.4 mealybug eggs or 37.6 per day for 32.3 days; while at 70°, 29.2 eggs were eaten each day for 43.9 days, making a total of 1279.8 eggs eaten by each larva and thus indicating the greatest protection against mealybug damage.

Preliminary experiments in feeding adult beetles on adult mealybugs indicate that a beetle will eat about 1½ mealybugs per day at 80°, and half a mealybug per day at 60° and 70° F.

Control of Red Spider. (W. D. Whitcomb, Waltham.) In studies of insecticides used for the control of red spider on carnations and greenhouse plants, materials containing rotenone continued to show a high toxicity against this pest and generally became more effective as the temperature increased. The addition of wettable sulfur as a fungicide to one of the rotenone sprays caused no material change in the number of red spiders killed. In comparable tests most of the newer commercial insecticides containing rotenone were inferior to the older standard mixtures or to laboratory preparations. Suspensions of derris, cube, or pyrethrum powder in water were less effective than the extracts of these materials, and the addition of a wetting agent did not increase their effectivness in the laboratory.

A commercial potassium-seleno-sulfide spray was only moderately effective, and the addition of wettable sulfur increased the value of the combination only slightly. With this material the percentage of spiders killed was greater 5 days after spraying than it was after 10 or 15 days, but the number of live spiders on the sprayed plants was much smaller after 15 than after 5 days.

Lubricating oil emulsions were more effective at 60° F. than at 80° but the more volatile kerosene emulsion was more effective at 80°.

Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb, Waltham.) Preliminary studies of naphthalene derivatives indicate that these materials are quite toxic to red spider and have promising possibilities as greenhouse fumigants.

In experimental fumigations using the materials at the rate of ½ ounce per 1,000 cubic feet vaporized in 6 hours at a temperature of 70° F. and a relative humidity of 60-65 percent, 75 to 95 percent of the red spiders were killed in one fumigation, and 95 percent or more in two fumigations. Naphthalene base materials in the form of oils or light waxes vaporized satisfactorily, but the heavier waxes gave off a thick smoke and a powdery precipitate which made them undesirable for practical use. When 1 part of wax was dissolved in 2 parts of oil, each of the combinations used killed 60-70 percent of the spiders in one fumigation, and about 95 percent in two fumigations. The addition of naphthalene or paradichlorobenzene crystals to the oil gave similar results. Crude forms of the naphthalene base oils and waxes were less effective than the more refined forms. Although the safety of these materials to plants has not been definitely determined, no serious injury has resulted so far.

In cooperation with the Boston Edison Company, an electrically controlled fumigating stove for use with naphthalene and similar compounds was developed and tested. This unit, which was composed of electric heating elements and a container for the fumigant, was designed to fumigate 7,000 to 10,000 cubic feet. The heat was adjusted by a series of contact switches and a rheostat having a range of approximately 75 to 175 watts, producing a temperature of 150° to 400° F. in the fumigant. When this unit is adjusted, the fumigant will be vaporized at a uniform rate automatically. The operating cost for these units is surprisingly low but at present the manufacturing cost is high.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920 Chapter 94)
Seed Control (General Laws, 1927 Chapter 94)
Dairy Law (General Laws, 1920 Chapter 94)
Advanced Registry Testing
Miscellaneous Work

Feed Control. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski, F. A. McLaughlin, J. T. Howard.) During the fiscal year 1,791 samples of feeding stuffs were officially collected and examined in the control laboratories. The gross receipts from the registration of feeding stuffs in 1937 (calendar year) were $23,020, derived from 1,151 brands at $20 each.

Dairy Law. (P. H. Smith, J. T. Howard, H. L Allen.) During the year ending December 1, 1937, 6,686 pieces of Babcock glassware were tested. Condemned glassware consisted of one pipette. One hundred certificates of proficiency were awarded; and 224 creameries, milk depots, and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, one machine was condemned.

Advanced Registry Testing. (P. H. Smith.) Advanced registry testing has been supervised by this department since its beginning in 1902. There are now on yearly test 386 cows located on 45 different farms. This does not include the herd tests where all animals in each herd are placed on test. There are 39 of these, 6 of which are supervised by men sent out from this office and 33 by cow-test association supervisors.

Miscellaneous Work. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski.) Numerous analyses have been made for residents of the State and other departments of the college.

Summary of Miscellaneous Work, 1937

Materials sent in:	
Milk and cream, butterfat only	919
Milk, solids and fat	27
Ice cream, for fat	96
Feeds, from farmers and dealers	98
Feeds, from State Institutions	235
For other departments of Experiment Station and College:	
Dry matter, forage crops	385
Complete fodder analyses	37
Vegetables, fiber only	60
Grass and hay, water and protein	158
Feeds, fat and fiber	57

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, J. W. Kuzmeski, A. F. Spelman, Chemists; L. A. Graves, C. L. Whiting, G. E. Taylor, Sampling Agents; Harry L. Allen, Laboratory Assistant.) Records for the year show that 117 firms have registered for sale in the State of Massachusetts 497 brands of mixed fertilizer and fertilizing materials and 51 brands of agricultural lime and gypsum. Results of analysis show that 68 percent of the mixed fertilizer brands, 79 percent of the unmixed fertilizer brands and 80 percent of the lime brands showed no deficiencies. The gross receipts from the registration of the fertilizer and lime products and from fertilizer tonnage fees for the year 1937 were $15,372.19.

For about ten weeks, beginning April 1, three experienced men employed to draw samples for inspection purposes sampled 21,314 sacks or containers, representing 17,858 tons of materials; 191 towns were visited, and 1,819 samples representing 549 brands were drawn from stocks found in the possession of 599 agents or owners. The following summary shows the character of these substances, as well as statistics with reference to their inspection.

	Brands Registered	Brands Collected	Samples Drawn	Number of Analyses	Number of Determinations
Mixed fertilizers	307	308	1,028	444	7,967
Ground bone, tankage and fish	45	45	151	69	708
Nitrogen products, mineral and organic	53	50	205	115	522
Phosphoric acid products	26	26	109	31	276
Potash products	17	17	69	28	145
Dried pulverized natural manures	32	31	107	35	335
Nitrate of potash	5	5	11	5	36
Peat products	3	3	4	3	30
Wood and cotton hull ashes	7	6	12	12	99
Miscellaneous	2	6	10	6	98
Lime products	53	54	25	56	591
Totals	550	551	1,831	804	10,807

During the period July 1, 1936 to July 1, 1937, the tonnage of fertilizer and plant food sold in Massachusetts was as follows:

		Plant Food Elements (Tons)		
	Fertilizer (Tons)	Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	48,527	2,548	4,138	3,468
Unmixed fertilizer chemicals and materials	24,004	1,579	2,376	821
Pulverized natural manures	1,743	36	26	44
Totals	74,274	4,163	6,540	4,333

Full details of the fertilizer and lime inspection will be found in Control Bulletins 90 and 91.

Miscellaneous Analytical and Diagnostic Work. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski.) Chemical studies in cooperation with several departments of the Experiment Station, Field Station, County Agents and men in charge of the Soil Conservation work of the state have been carried on. The character and extent of this work is shown in the following summary:

Apple spray residue	17
Apples for borax test	3
Agricultural lime products (Soil Conservation work)	12
Cranberry spray residue	1
Dog rations	2
Fertilizer mixtures and chemicals	26
Fertilizers for research studies on magnesium and manganese	7
Field crops	44
Garbage incinerator ashes	1
Nicotine solutions	1
Salt lick	1
Total	115

Other work of the department has included consultations on various projects where chemical problems were involved. Research on problems developed by the referees of the Association of Official Agricultural Chemists of North America has received the usual attention and has included work on methods for the determination of magnesium oxide and manganese in fertilizer mixtures, the chemical work involved in these studies being performed by Mr. J. W. Kuzmeski. A considerable variety of chemical work has, as usual, been done for other State Institutions, community organizations, firms and individuals having problems of agricultural interest. This group includes the analyses of the following materials:

Animal tissues for mineral poison	3
Ashes of various kinds	4
Dried pulverized manures	5
Food and forage products for mineral poisons	8
Fertilizers and fertilizer chemicals	15
Fire-damaged fertilizer	6
Industrial by-products	8
Lime products	6
Miscellaneous	2
Soils	11
Total	68

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) Rust resistance tests of approximately 50 species and strains of snapdragons in the field indicate that there is a wide variation in the degree of resistance to rust. Only six species of the total number studied showed no susceptibility; in a few cases the number of plants tested was so small that results are not considered conclusive.

Commercial garden varieties of snapdragons sold as rust-proof strains showed a high degree of resistance to rust, but such varieties are still in need of further selection for trueness to color and type of plant growth. Of 25 varieties tested, only six showed a high degree of purity in color and type of growth.

Some 35 commercial varieties of greenhouse snapdragons were tested for rust resistance under glass and, while there was some difference in degree of susceptibility, none were observed to be resistant. There was considerable variation in germination of seeds of commercial varieties which appeared to be due to immaturity of the seed.

Work with the development of Field Station strains of rust-resistant snapdragons is progressing. Winter flowering types which show promise have been developed for use under glass. Considerable difficulty has been experienced in getting rust resistance, color of flower, type of spike, and the winter-blooming character combined in one strain.

Study of the Effect of Plant Nutrients, Soil Reaction, and Light on Gardenias. (Harold E. White, Waltham.) On the basis of experimental results, preventive rather than corrective measures appear to be a more practical method of regulating iron chlorosis of gardenias. For three years it has been possible to prevent iron chlorosis consistently by keeping the fertility level of the soil low and by using a fertilizer mixture containing nitrogen in the form of organic materials such as tankage, milorganite, cottonseed meal, or in the form of ammonium sulfate. Fertilizer containing as low as 1 percent of nitrogen from sodium nitrate or calcium nitrate was sufficient to cause chlorosis. It is questionable whether an actual deficiency of iron occurs in the soil or whether iron compounds remain inactive in the soil. What would appear to be a more plausible explanation of chlorosis in gardenias is that antagonism between iron and certain nutrient elements — possibly calcium or sodium — takes place within the plant. Sulfur in a quantity as low as one half pound per 100 square feet of bench area was sufficient to prevent chlorosis; however, in quantities above one pound it had a definite retarding effect on the growth of the plants.

Phosphorus and potassium do not appear to have any influence on chlorosis. Added illumination of 25 to 50 foot-candles of light for 6 hours each day from September 1 to April 1 had no effect on chlorosis. Low growing temperatures were observed to produce a type of chlorosis which did not respond to iron treatments to the foliage and did not appear to be corrected by applications of ammonium sulfate.

Analytical data on chlorotic and normal plants show that plants fed with sodium nitrate were lower in iron content than plants fertilized with ammonium sulfate; also, sulfur increased the iron content of plants even though they were fed with sodium nitrate. Soil acidity does not appear to be a specific cause of iron chlorosis, as chlorotic symptoms occur over a wide pH range.

Propagation Studies with Gardenias. (Harold E. White, Waltham.) Technique and propagation methods do not appear to be concerned appreciably with the successful rooting of gardenia cuttings.

Propagation Studies with Geraniums. (Harold E. White, Waltham.) Losses of geranium cuttings by florists who propagate plants would appear to be due to black stem rot disease. Isolation and inoculation studies indicate that several fungus organisms are concerned in the rot of the cuttings. Treatment of the cuttings with different disinfectants and the sterilization of the propagating media had no effect in reducing the rot disease. Synthetic growth substances did not appreciably stimulate rooting of geranium cuttings.

Temperature experiments relating to the rooting of geranium cuttings show that at a temperature of 60° F. the rot disease is less destructive than at higher temperatures. Geranium cuttings taken from stock plants grown under glass gave a higher percentage of disease-free rooted cuttings than did cuttings from field-grown plants. Bordeaux spray applied to plants in the field appeared to be harmful rather than beneficial, since cuttings from sprayed plants did not root as well as those from unsprayed plants.

Effect of Temperature on Forcing Lilies. (Harold E. White, Waltham.) A rooting temperature of 60° F. was found to be better than 50° for bulbs of *Lilium longiflorum* var. *giganteum.* The response was the same for southern-grown Japanese bulbs of 7-9 and 9-10 cm. in size. The blooming period was 10 days to 2 weeks shorter when bulbs were rooted at a temperature of 60° than when they were rooted at 50°. Bulbs rooted at temperatures of 70° and 80° and then grown in a temperature of 60° developed and flowered normally. Bulbs rooted at a temperature of 50° averaged 3.8 flowers per plant; at 60°, 4.3 flowers; at 70°, 3.85 flowers; and at 80°, 3.0 flowers per plant. On plants rooted in temperatures of 70° and 80° the internodes were longer than on plants rooted at 50° and 60°. Changes in growing temperatures at various stages of bud development did not cause splitting of the buds.

DEPARTMENT OF HOME ECONOMICS NUTRITION

Helen S. Mitchell in Charge

Cause and Control of Nutritional Cataract. (H. S. Mitchell and G. M. Cook.) Medical authorities state that there is as yet no effective therapeutic agent for the prevention or cure of cataract. While experimental cataract produced in rats may be quite different from a senile or other type of cataract in man, yet the lens is opaque in both cases and the mechanism of the change is unknown. The experimental approach with animals which have proved susceptible to this pathological change promises to yield results of fundamental importance which may ultimately suggest some effective clinical procedure.

The incidence and rate of development of cataract in rats may be controlled with some degree of accuracy by the amount of galactose fed, thus providing an experimental device for studying the possible influence of other dietary factors upon cataract production.

1. *Effect of other dietary constituents upon the cataract-producing action of galactose.* The cataract-producing action of lactose or galactose rations was not appreciably altered by

1. type of supplementary carbohydrate
   (starch, dextrine, sucrose, glucose).

2. type of fat (crisco, butter, mutton
   tallow, cod liver oil) or amount
   (2, 11, 22, and 44%).

3. addition of excess cholesterol
   (2½ and 5%).
4. amount of salt mixture
   (0, 4 and 10%).

5. shifting acid-base balance
   (4.76% Na citrate, 3.4% NH_4Cl).

6. amount of water ingested.
7. vitamin C administered orally or injected.
8. deficiency or excess of vitamins B_1 and B_2.
9. ingestion of large doses of dinitrophenol.
10. injection of lens antigen (from beef, sheep, guinea pig and rat).

These results were published in abstract form in the *Journal of Nutrition*, Volume 13, Supplement, page 18, 1937.

The type and amount of protein in the ration does exert a definite influence upon the rate and incidence of galactose cataract. Earlier work with protein variations failed to show significant differences because the proportion of the aggravating factor, galactose, was evidently too large. Subsequent work with lower levels of galactose (15% and 25%) has demonstrated that deficient protein (5%) markedly hastens cataract development and high levels of protein (45%) inhibit cataractous changes. Six different proteins from widely varied sources (casein, lactalbumin, beef, fish, egg albumin, and soy bean) are now being investigated and preliminary observations would indicate that the protective action against cataract is not the same for all nor does it correlate with their growth-promoting properties.

The demonstrable loss of sulfur-containing compounds from cataractous lenses suggested that the sulfur-containing amino acids might be crucial factors in metabolic problems. Large doses of cystine (1, 2, and 3%) had but a slight inhibitory effect and methionine is still under investigation. Preliminary findings were reported in the *Proceedings of the Society of Experimental Biology and Medicine*, 36:806, 1937.

2. *The relation of ingested carbohydrate to the type and amount of blood and urine sugar and to the incidence of cataract in rats.* A summary of this work was given in the 1936 *Annual Report* but publication was in the *Journal of Nutrition* 13:501, 1937.

A Study of the Nutrition of College Women with Respect to Vitamin C Requirements. (H. S. Mitchell and O. A. Merriam.) This project, initiated in the fall of 1936, is concerned with the vitamin C intake and excretion of groups of students most of whom are eating at the college cafeteria. The women of the classes of 1940 and 1941 have been experimental subjects during their freshmen year. The data accumulated to date seem to indicate that many students are borderline or below in their vitamin C intake as compared with generally accepted standards. A possible correlation of these findings with other measures of health or well-being is being investigated. The project will be continued for the balance of the school year.

The Relation of Iodine or other Minerals to the Prevention of Cholesterol-induced Atherosclerosis in Rabbits. (H. S. Mitchell and M. Goldfaden.) This research is being sponsored by the Lang Fund. It has been successfully demonstrated that gross pathological lesions of the aorta may be produced by feeding cholesterol to rabbits. When the amount and time of cholesterol feeding is so controlled as to produce moderate aortic lesions, litter-mate rabbits fed kelp in the ration along with the cholesterol may be partially or completely protected against these pathological changes whereas potassium iodide fails to give this protection. The cholesterol content of the blood of rabbits on these experiments indicates that there is some correlation between the circulating cholesterol and aortic lesions. Growth and general condition of the rabbits have continued satisfactory throughout the experiments. This study is still in progress.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Cranberry Research. (C. R. Fellers, A. S. Levine, and W. B. Esselen, Jr.) This project has been supported in part by the American Cranberry Exchange. The use of dextrose in canned cranberry sauce is satisfactory provided the ratio of dextrose to sucrose does not exceed 1:3.

Cooperative cranberry storage experiments conducted for two years show that temperatures of 35°-40° F. are superior to higher temperatures for storing either semi-ripe or ripe Early Black and Howes cranberries. A paper entitled "Gas content of cranberries and possible relationship of respiratory activity to keeping quality" was published in *Plant Physiology* 12:527-536, 1927.

Cranberries contain approximately .03 percent total iron, 31 percent of which is "available" iron as determined by the alpha, alpha-dipyridyl method. Hemoglobin regeneration tests with anemic white rats fed cranberries as their source of iron also showed that about one third of the iron present was available. Cranberries are also relatively high in manganese and copper. At the present time the influence of cranberries in the diet on the utilization of calcium by the white rat is being studied. A paper entitled "Influence of certain fruits on fecal flora and intestinal reaction in diets of rats" was published during the year in *Food Research* 2:65-72, 1937.

Technological Investigations on Apples. (C. R. Fellers, A. S. Levine, J. A. Clague, and W. B. Esselen, Jr.) The work on canned baked apples has been continued. Among the better varieties for the purpose are Rome, King, York, Stayman, and Jonathan. Details of the canning process are being studied.

Cider champagne and other bottled apple beverages have been manufactured with a view to utilization of culls to better advantage than is now done. These beverages contain practically no vitamin C. By clarifying with commercial pectinase enzymes, very clear, attractive beverages can be prepared.

McIntosh and Baldwin apples, to the amount of 500 and 1000 grams daily, were included in neutral and acid-forming diets and eaten by young men. Blood alkali reserve was unchanged and urinary acidity but slightly increased as a result of the consumption of these large quantities of apples.

Currant Jelly. (J. Novick and C. R. Fellers.) A study has been made of the factors affecting yield and quality of currant jelly. Some of these factors are variety, maturity, extraction methods, concentration, finishing point criteria, and storage of the extracted juice. Accumulated data indicate that juice viscosity is a satisfactory criterion of jelly strength and yield. Since the currant contains no starch, treatment of the juice with diastatic enzymes has been of little value for clarification. Currants contain a little vitamin A and are an excellent source of vitamin C, but most of the vitamin C is lost during the process of manufacturing jelly.

Nutritive Value of Frozen Foods. (C. R. Fellers, C. F. Dunker, and D. De Felice.) A chemical method suitable for carotene determination in fruits and vegetables has been perfected and used to evaluate 18 fresh and frozen products for carotene content (vitamin A). The standard rat bio-assay method for vitamin A has been used to check the chemical determination in several cases. Spinach, squash, peas, snap beans, asparagus, broccoli, and carrots, in either the fresh or the frozen state, are good sources of vitamin A.

A careful study has been made for two seasons of the losses in vitamin C of spinach due to shipment, freezing, canning, cooking, and dehydration. The steam cooking of spinach with but little water caused much better retention of vitamin C than did water cooking (320 units per ounce as compared with 156 was the average for 10 samples). Only moderate losses of vitamin C resulted from either freezing or canning. Dehydration caused complete loss of vitamin C and markedly decreased the vitamin A content. Freezing and canning of spinach had little effect on its vitamin A content.

A paper covering research on sweet corn was published in *Food Research* 2 (1):41-50, 1937.

Nutritive Value of Industrial Food By-Products. (C. R. Fellers, W. B. Esselen, Jr., J. Bernotavicz, and A. D'Ercole.) Work has been in progress on tomato and cranberry wastes, apple pomace, dried buttermilk, and distillers' wastes. Tomato waste consists of seeds, skin, and fiber and contains approximately 24 percent protein, 15 percent fat, 32 percent carbohydrates, 3 percent ash, and 20 percent crude fiber. Present also on a 100-gram basis are 680 international units of vitamin A, 300 Sherman–Bourquin units of vitamin G or 200 Norris–Wilgus chick units, 500 Sherman–Chase units of vitamin B, and a small amount of vitamin C. This product possesses distinct value as an animal and poultry feed but must be used with some caution because of poor palatability.

Dried distillers' grains and concentrated slop or syrup were likewise examined chemically and biologically. Both are good sources of vitamins G and B, but the growth-promoting quality of the proteins is poor unless they are supplemented with casein or other proteins.

Research is now under way to determine whether apple pectin (derived from pomace) has a vitamin A-sparing action and whether the presence of pectin in the diet affects the mucous membranes and mucin formation. No significant results are available.

Vitamin D Investigations. (W. B. Esselen, Jr., and C. R. Fellers.) Rickets resistance in rats cannot be correlated with either environmental temperature or diet ingredients within limits. The cause of spontaneous recovery in a colony following a period of rickets resistance is unknown.

Collaboration with committees of the A. O. A. C. and the American Public Health Association in referee work in connection with the establishment of standard assay methods of vitamin D has been continued.

Bio-assay of numerous samples of irradiated, fortified, and metabolized vitamin D milks produced in this State showed that the guaranteed amount of vitamin D was present in these milks and that they could be safely recommended as potent sources of vitamin D.

Various samples of poultry feeds and other preparations have been assayed for vitamin D.

Nutritive Value of Fishery Products as Human and Animal Food. (Cooperative with Chemistry. C. R. Fellers, W. S. Ritchie, J. A. Clague, and W. B. Esselen, Jr.) A paper was published (*Trans. Amer. Fish. Soc.* 66:415-421, 1937) on the nutritive value and utilization of the Atlantic Whiting, *Merluccius bilinearis*.

Home Canning Research. (A. S. Levine, W. A. Maclinn, and C. R. Fellers.) A bulletin (No. 341) covering the research and field work on vacuum–pressure relationships in glass canning jars was published this year. Three years' experience has demonstrated the value and utility of this new method of home canning wherein the wire bails on the glass jars are tightened *previous* to heat treatment. The method decreases markedly the losses of liquid from jars during processing, improves the appearance of the contents, saves time, obviates the necessity of handling the hot jars after processing, and has no effect on either breakage or spoilage.

Work is under way on the utilization of cull turkeys by canning as meat and in the form of sandwich spreads and broth.

Ascorbic Acid in Tomatoes and Tomato Juice as Affected by Maturity, Variety, Method of Assay, and Other Factors. (W. A. Maclinn, A. S. Levine, and C. R. Fellers.) A second season's results on tomato varieties and strains have been obtained. The same varieties which were high in ascorbic acid in 1936 were likewise high in 1937. However, all varieties contained 20 to 35 percent less ascorbic acid in 1937 than in 1936. Hence, seasonal and varietal differences may greatly alter the ascorbic acid (antiscurvy value) of commercial tomato juices. Tomatoes picked when partly ripe are of the same ascorbic acid content as either freshly picked or stored ripe tomatoes. Preliminary data indicate that tomato juices canned either in glass or in tin containers do not decrease significantly in ascorbic acid content in four months' storage in subdued light at room temperatures.

Use of Corn Sugar in Fruit Products. (C. R. Fellers, C. W. Morrison, and H. A. Howard.) A paper summarizing results to date was published in *Indus. and Engin. Chem.* 29 (8):946-949, 1937. The work is being continued.

Possible Nutritional Aspects of Arthritis. (W. B. Esselen, Jr., and C. R. Fellers.) This research, conducted under the Lang Fund, has shown that iodine, kelp, or vitamins B, G, and D in the diets of rats and guinea pigs have no effect on the onset or the pathology of scurvy or the length of life of the scorbutic animal. The data show the great specificity of vitamin C and that the results of a deficiency of it cannot be influenced by minerals or by large amounts of vitamins B, G, and D. However, it was found that vitamin D did have a favorable action in decreasing the marked joint swelling ordinarily observed in severe scurvy.

Vitamin Content of the Maize Plant and Grain. (W. B. Esselen, Jr., B. Isgur (Agronomy), and C. R. Fellers.) A paper was published on this subject in *Jour. Nutrition* 14 (5):503-511, 1937.

Does Fertilization of Plants Affect Their Vitamin C Content? (B. Isgur (Agronomy) and C. R. Fellers.) Preliminary data have been published in *Jour. Amer. Soc. Agron.* 29 (11):890-893, 1937.

DEPARTMENT OF HORTICULTURE

R. A. Van Meter in Charge

Horticultural Value and Culture of Perennial Asters. (Ray M. Koon, Waltham.) The purpose of this study is to evaluate all the horticultural varieties and certain promising species of the genus Aster for garden use, discover the proper cultural methods, and develop new varieties of habit and color nonexistent at present. Inasmuch as Aster is a genus of nearly 2,000 species and synonyms of very intricate taxonomy, there is nothing to be gained by becoming involved in species-complexes.

Three hundred and twenty-five species and varieties assembled at Waltham from sources in America and abroad have revealed that (1) many varieties in the trade should be eliminated from nurserymen's lists and supplanted by others of proved higher garden value; (2) certain varieties originating abroad have been renamed upon their introduction to the American trade, resulting in confusion as to nomenclature; (3) type species have been given horticultural names for the purpose of popularizing them commercially; (4) a few of the spring flowering species, namely subcaeruleus, alpinus and purdomi, can be forced during the winter under glass and may prove to be a profitable crop for the florist.

Data have been recorded as to the flowering date and duration of bloom, habit of growth, diameter of flower, and color of rays. Ridgway's Color Standards and Color Nomenclature has been used in identifying and designating the colors.

A list of recommended varieties for nurserymen to propagate and for gardeners to grow has been prepared.

At the request of the American Joint Committee on Horticultural Nomenclature the investigator has revised the list of Asters for the 1938 edition of Standardized Plant Names.

Transplanting and Packaging of Hardy Plant Materials. (George Graves, Waltham.) Seedlings of superior strains of hybrid Delphiniums, sown in two-inch pots in August 1936, transferred to tin pots of 3.6-quart capacity and eight-inch porous clay pots in October, and then carried over winter in a cold greenhouse (40°-45° F.), became thoroughly established in the containers, made little winter top-growth, and in late April or May (depending on individual vigor) were merchantable plants, each with one or more normal flower spikes. When planted in the field after first flowering, a heavier second and, in some cases, a third flowering took place. In this single test the impervious containers required less attention in winter and gave plants of more uniform growth.

Dormant field buds of Hybrid Tea Roses, potted in tins and clay pots in late November and carried over winter plunged in cold frames, made up into salable plants by midsummer. This preliminary trial in frames showed greater economy and more uniform results than did wintering the buds in a temperate general-purpose greenhouse without thought to the specific cultural requirements of the rose or to breaking of dormancy.

No growth differences were noticeable between checks and treatments on a test of spring-planted *Taxus media* var. *Hicksii* when colloidal waxes were applied to foliage and branches after receipt bare-rooted from another state.

Plants of some of the newer varieties of apples on Malling type stocks Nos. 1 and 4 which are being trained in eight-inch pots this year showed the characteristic influence of dwarfing understocks in that they did not put on late growth as in their first year after potting.

Plants now being grown to test locally produced forcing Lilacs in the winter of 1938-39 withstood the shock of potting in full leaf in early September, thus confirming the practice of handling field Lilacs in early autumn.

Clonal Apple Investigation. (George Graves, Waltham.) Preliminary efforts to build up a stock of plants for study is yielding a mixed assemblage of layers, sucker plants, vertically placed root cuttings which have regenerated top and roots, independently rooted etiolated shoots from horizontally placed root pieces and, in the case of one seedling of ornamental use, a few hardwood cuttings. These various sorts of plants are being produced entirely in the open field and without recourse to the application of auxin.

Preliminary comparison of results of these well-understood field methods of increase (from the point of view of the desirable properties of a satisfactory understock) indicates favorable promise on the part of etiolated shoots from horizontally placed root pieces.

Study of Hardy Ornamental Plant Material. (George Graves and Harold S. Tiffany, Waltham.) Of the 1340 species and varieties under observation at the beginning of the year, 128 were lost through death or through discard because of worthlessness or redundancy. Further accessions then brought the collection up to a total of 1551 at the year's end. A continuing system of accurate graphic blooming records was started this year for all plants under observation.

Although all effort in this project is working towards evaluation of garden plants, particularly herbaceous materials, special emphasis is being placed on a few of the most confused groups, such as Hemerocallis, Garden Phlox, and Oriental Poppies. Of these three groups, the Daylilies have been well enough studied to show that, in the absence of standards for judging, many worthless or duplicate varieties have been introduced, also that commercial stocks are quite mixed. Sufficient data are yet lacking to permit determination of outstanding varieties.

Much of the herbaceous test material was this year mulched heavily with hay or shredded banana stems after the first spring hoeing and fertilizing. As has been reported elsewhere, mulching proved beneficial for large woody plants, both culturally and economically.

DEPARTMENT OF OLERICULTURE

Grant B. Snyder in Charge

Packet Seed Studies. (G. B. Snyder and W. L. Lachman.) A large majority of home gardeners buy their vegetable seeds from the neighborhood store in either packet or bulk lots. It has been found that seeds purchased in this manner frequently have a variable germination and are not true to the name under which they are sold. In order to check these factors, state inspectors purchased some 168 lots from various stores in the State. These included fifteen of the more important vegetables: beans, beets, carrots, cucumbers, sweet corn, tomatoes, cabbage, lettuce, onions, parsnips, peppers, radishes, spinach, and turnips.

Field notes on germination indicated fair to good vitality in most lots. There was some variation in trueness to name in the carrots and beets. Most of the other vegetables were within the type range.

Systematic Studies of Vegetables. (A. P. Tuttle, P. W. Dempsey, and G. B. Snyder.) During the past few years a large number of improved and new varieties of vegetables have been offered to the vegetable grower. Many of these newer sorts were planted in the trial plots along with the more standard sorts and comparatively evaluated for performance, quality, and adaptability to Massachusetts conditions. Some one thousand different lots covering more than 50 different kinds of vegetables were included in the trials.

Water Requirement of Vegetable Crops. (W. L. Lachman and G. B. Snyder.) Tomato plants grown in pots in the greenhouse responded well to heavy watering and the plants receiving the most water outyielded those plants with smaller applications. Applications of water in varying quantities to tomatoes also appear to influence the prevalence of blossom end rot. Studies conducted in the greenhouse indicate that heavily watered plants are as susceptible to blossom end rot as those which receive light applications of water.

Vernalization of Vegetable Crops. (W. L. Lachman.) While rutabagas may be vernalized, seed of cabbage soaked in water for twenty-four hours and stored at 0° C. for twenty-eight, forty-two, and fifty-six days have not thus far produced plants which initiate a flower stalk before a head.

Lettuce seed soaked in water and stored for ten days at 0° and −5° C. produced plants which initiated flower stalks earlier than those from seed not so treated.

Shape Index Studies of Tomatoes. (W. L. Lachman.) A study of ten strains of tomatoes on a quantitative basis revealed that there were no consistent changes in the shape of fruits during the season. A random sample of twenty-five fruits proved to be sufficient to accurately describe the shape of these varieties at any given period of time. There was a tendency for the largest fruits to be the flattest and at the same time the most irregular and ribbed.

Asparagus Investigations. (Robert E. Young, Waltham.)

Varietal Improvement. Individual harvest records for the selected asparagus plants were obtained, and these data completed the records necessary to correlate the relationship between the number of stalks produced during summer growth and the subsequent number and weight of spears produced during the next cutting season. There was found to be a very close relationship between growth and yield. This association permits the asparagus seed grower to select seed from the high-producing plants, thus making an improvement in the strain. The results of this investigation on relationship between growth and yield were presented for publication in *Amer. Soc. Hort. Sci. Proc.* 34, 1937.

Depth of Planting and Height of Cutting. There has been no change in the effect of the depth of planting on the yield of asparagus in this experiment during the last two years. This past season there was no difference in yield when the asparagus spears were cut with 8 inches of green or with 12 inches of green. The yield from the plot cut with 4 inches of green was considerably less than that for the other two plots.

The length of spear and production for the past season was as follows:

Len th of Spear	Average Yield per Plant (Grams)	Average Number of Spears per Plant	Weight per Spear (Grams)
4 inch Green	310	19.0	16.3
8 inch Green	461	15.3	30.1
12 inch Green	472	11.3	42.9

The data indicate that the asparagus plant continues to send up spears until all the reserve food is exhausted. The number of spears that plants will produce seems to depend on the size of the spear and the length to which it is allowed to grow. If the spears are cut too short, there is an insufficient number of buds on the asparagus crown to utilize all the reserve food supply of the plant.

Pascal Celery Storage. (Robert E. Young, Waltham.) The results of the storage experiments conducted during the past season confirm earlier results. Two experiments were conducted in growers' pits to determine whether results could be obtained under commercial storage similar to those obtained in the experimental storage. One of the growers obtained a 10 percent increase in marketable celery where the plants were packed loosely. This celery would have kept considerably longer had it been left in the pit. Celery packed in the regular way was mature and beginning to decay, at the time it was cleaned for market. Similar results were obtained in the other grower's pit except that the celery did not keep quite as well due to a different method of storage.

In the storage pit at the Station, the yield of marketable celery was almost one third greater when the celery was packed in the pit loosely enough to permit circulation of air than when it was packed tightly, as in commercial practice.

A paper presenting some of the results of heart growth studies with pascal celery has been published in *Amer. Soc. Hort. Sci. Proc.* 34, 1937.

Trellis Tomato Experiments. (Robert E. Young, Paul W. Dempsey, Harold A. Wilson, Waltham; Alden P. Tuttle, Amherst.) The trellis tomato crop for the past season was above the average in production. The foliage remained green all the way down the plant until frost. With such a good crop, many of the differences due to treatment that were observed last year were lacking this past season. The most outstanding treatment was the use of potted plants trained to a single stem. Plants treated in this manner produced almost twice as many early fruits as did the plants that were pricked out and then trained to two stems. All fruits picked before the price on the Boston Market dropped below one dollar per basket (24 pounds) are classed as early. This season the price received for early fruit was about three times as great as that received for the remainder of the season. Trellis tomatoes produced three times as many early fruits as did the same variety (Comet) when grown flat culture.

The soil on which the tomatoes were grown was a good loam and when weather conditions were favorable the various fertilizer treatments failed to affect the yield.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.)

Waltham Scarlet Shell Bean. Questionnaires sent to growers who had planted samples of this bean indicate that the growers consider it superior to other strains. The replies indicate that shell beans are one of the most difficult crops to grow and produce a first-class crop. On certain types of land the Waltham Scarlet does not do well. In general, this bean is increasing in popularity and there is insufficient seed available to supply the demand.

Waltham Beauty Pepper. During the past season, this pepper has continued to find its place and is increasing in popularity, particularly among home gardeners. It has proved to be a good pepper when grown within and north of Massachusetts, but when grown farther south it has a tendency to be shorter on the longitudinal axis. Plenty of seed of this variety is available.

Lettuce. Considerable progress has been made toward the production of a better acclimated New York type lettuce for Massachusetts. This project is in cooperation with the Division of Fruit and Vegetable Crops and Diseases of the United States Department of Agriculture. Selections from Columbia No. 1 which was developed by the cooperating agency have proved superior to the parent stock and considerably better than New York No. 12, the standard variety used by growers. This project has not been continued long enough to determine the value of the many lots of hybrids now in trial.

The F_3 generation of a cross between Bel-May, the forcing lettuce, and an English strain has produced a very promising crop in the greenhouse. The new hybrid has a better color and frame than Bel-May but has a slightly small head for our market. The hybrid will be back-crossed to Bel-May this year to further increase its size.

Tomatoes. The Waltham Forcing Tomato has continued to gain in popularity during the year. Almost all greenhouse growers who have tried this tomato have been able to obtain a better crop of higher quality tomatoes than with any other variety or strain tried.

Samples of the Waltham Forcing and a new Trellis Tomato No. 22 were sent to many trellis tomato growers. Many greenhouse growers who have been using the Waltham Forcing inside have also tried it outside. In general, both varieties have set a satisfactory crop but on some farms the fruit has been too small. At the Field Station the fruit has averaged four to five to the pound for the total crop. The particular advantage of these strains of tomato over other varieties that have been tested at the Field Station is the larger percentage of number one fruit produced. During the past season some varieties produced as low as 16 percent number one fruit, while practically all the Station strains were above 50 percent, and a few produced 75 percent number one fruit. Further testing will be necessary before either of these varieties can be recommended with assurance.

Hutchinson Carrot. The supply of stock seed of the Station's strain of this carrot was maintained and increased. The use of this carrot has increased slightly during the year. Most market gardeners have expressed satisfaction with the carrot, but from the standpoint of consumers a better core and internal color would be an improvement. F_2 generation hybrids of Hutchinson crossed with a dark-colored selection of Tendersweet produced a very good colored crop of the same shape as Hutchinson. Due to the biennial habit of the carrot it will require several years to obtain a uniform strain. In testing carrot seed collected by the Bureau of Foreign Plant Introduction, one lot of seed was found that had exceptionally good color and a long root. A hybrid between this carrot and the Hutchinson carrot should have an extra small core of very good color.

Wyman Crosby Beet. The Field Station strain of Wyman Crosby beet has been perfected to the point where all characters are sufficiently satisfactory except the internal color. This beet when grown in the hot weather produces a high percentage of poorly colored beets; when grown in the cool weather of the fall, almost all of the beets are of a satisfactory color. Since the beet is a biennial and must be stored over winter, selection in the past has been made in the fall thus making improvement in color practically impossible. The method of selection has now been changed; the use of cold storage and the greenhouse has permitted the production of a crop during the summer. Approximately 90 percent of the roots were discarded in an effort to produce better color in future generations.

Cucurbita Pepo. No further progress has been made during the year in determining the genetics of the soft seeded character in some pepo crosses, due to the poor crop produced during the summer. This character does not seem to behave in a simple Mendelian manner, and the actual behavior has not been determined.

Rutabaga or Cape Turnip. At the request of growers in Bristol County, a large number of strains and varieties of rutabaga were collected for trial. Several of these were growers' strains obtained on the Cape and in Bristol County. It was determined that the growers' strains of white rutabaga were superior to any obtainable from seedsmen. This was probably due to the lack of importance of white rutabaga to the seedsmen. There is a lack of uniformity in all the strains of white rutabaga. Several seedsmen have fine strains of yellow rutabaga.

Greenhouse Cucumber. Powdery mildew on cucumbers is a serious disease of the greenhouse crop and a disease-resistant strain would be very desirable. In cooperation with Dr. Guba, Field Station Pathologist, 265 strains and varieties of Cucumis, imported and collected by the Bureau of Foreign Plant Introduction, were tested for resistance to mildew. No *Cucumis sativus* were found resistant although several *Cucumis melo* var. *Flexuosus* were resistant to cucumber mildew.

Blue Hubbard Squash. Very little progress has been made this season toward producing a good strain of Blue Hubbard Squash, due to the failure of most of the self-pollinated blossoms to develop. This lack of fertilization of the blossoms was due to the hot, dry weather that prevailed during pollination. However, it was determined from the yield data that growers' strain A is almost twice as good in a cross as growers' strain B. This elimination of many hybrids will permit a more concentrated effort on the desirable strains.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

The winter of 1936-37 was remarkably mild. The records of the Station show that the lowest minimum of the winter, 5° F., occurred on November 25 and 28. Winters with no subzero temperatures are very infrequent and the occurrence of the winter minimum in November is unprecedented. Peach buds came through the winter with little injury and the crop was good.

The summer was also in contrast with recent years because of abundant and well-distributed rainfall. Apple scab was more prevalent than for many years, but some fruit growers were able to combat it successfully and harvested clean crops. Brown rot of stone fruits was prevalent and strawberries rotted rather badly.

More than half the bearing apple trees in the experimental orchards were removed, having served their purpose in our investigations. The trees remaining bore a somewhat smaller crop than last year.

The Influence of Various Clonal Rootstocks on Apple Varieties. (J. K. Shaw and L. Southwick.) Experiments in propagation were continued. Most of the Malling stocks grew well from root cuttings taken from two-year-old nursery trees but there seemed to be differences with the different stocks. All attempts to root hardwood cuttings with and without treatments with different hormones failed. Budding these stocks was more successful than in the previous two years, due largely to more favorable moisture conditions.

The plants in the stock bed were all laid down horizontally and the new shoots hilled up with better success in producing rooted shoots. Stocks grown on short pieces of seedling nurse roots rooted well with most stocks.

Plans were made and trees budded for setting an orchard of certain varieties on certain Malling stocks to replace the old Stock and Scion Orchard which was removed in the spring of 1937.

In relation to this project about 2,000 trees budded on Malling stocks were planted in cooperation with twenty different commercial growers over the State.

The South Amherst orchard made little growth even with adequate summer rainfall and fertilization with manure. It is planned to make a study of the reason for the small growth of these trees.

The Malling stock orchard of McIntosh and Wealthy at the Station produced a good crop. There is a certain area where there are many trees making poor growth. Some of these were treated by injecting various combinations of fertilizer elements (including certain "minor elements") into the soil around the tree. No results were observed but this work will be continued.

Studies of the fruit suggest that the rootstock influences both size and shape of the fruit. They also show that the progressive decrease in size from year to year is greater with trees on the dwarfing stocks, especially on Malling IV. Trees on this stock seem to grow and mature very rapidly and may be expected to reach old age earlier than those on the usual stocks.

Tree Characters of Fruit Varieties. (J. K. Shaw and A. P. French.) A trip among nurseries, similar to the one made last year, gave further opportunity for study on this project. Special attention was given to sweet cherries and peaches. It is believed that the varieties of cherries commonly met with can be identified with certainty. Leaf serrations are of little value, but leaf shape, folding, and light reflections of the leaf are valuable. Considerable progress was made with peach varieties and plans are being made to grow a collection of varieties commonly found in nurseries for closer observation. These will be budded on red-leaved stock thus making it easy to avoid confusion from stock buds growing into trees. Another attempt to grow a more successful cherry nursery is planned.

Certification work under the auspices of the Massachusetts Fruit Growers Association was continued on the relatively small scale of the past few years. It seems that the simpler and less expensive practice of inspection where no tags are attached to individual trees is thought to be adequate by most nurserymen and fruit growers.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) As a result of the breeding work in 1936, there are in the nursery at the present time 373 selfed Oriole seedlings. This number represents about 50 percent of the seeds planted. Because rats destroyed part of the seed, it was not possible to get the exact percentage of germination. There are also in the nursery 250 selfed Elberta seedlings and a few cross-bred seedlings.

Since the winter of 1936-37 was a mild one, the bloom in the spring of 1937 was heavy and additional breeding work was done. Marigold and Oriole were again selfed to attempt to increase the population from these early varieties.

Another attempt was made to grow Marigold pits on a nutrient agar medium in bottles. This was more successful than in 1936, but still the percentage of germination was too small to be at all satisfactory. Pits from this variety were taken from the peaches as soon as they ripened, and immediately stratified in sand, to see if this treatment would induce germination.

The 1937 crop was good, but due to the wet season the fruit of many of the seedlings rotted before it was ripe and for this reason it was impossible to get observations on a number of seedlings. Additional evidence was obtained that there is a linkage between the free and the melting flesh characters in the Belle of Georgia variety and that there is crossing over to the extent of about 6 to 8 percent. Information was also obtained which points to a simplification of the confused situation which now exists in regard to the classification of the freestone, semi-cling, and clingstone groups of peaches.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) The Baldwin trees were removed thus leaving more space for the McIntosh trees. The crop was light and most of the trees are showing an increasing tendency toward biennial bearing. The same treatment as in recent years was continued but some changes are planned for next year. The two plots having a complete fertilizer continue to yield well; the cultivated plot with no fertilizer yielded better than in previous years. Evidently nitrogen alone is not a satisfactory fertilizer in this orchard, but how far these results can be applied to orchards on other soils is uncertain.

Comparison of Clover Sod and Grass in a Sod Mulch Orchard. (J. K. Shaw.) As recorded last year this project has been changed to a comparison of sod with a sawdust mulch, both with a complete fertilizer. The sawdust was spread about three or four inches thick, but failed to check the growth of grass very much. No injurious effect on the trees was noted. Further observations are needed before any conclusions can be drawn.

Comparison of Cultivation and Heavy Mulching for Apples. (J. K. Shaw.) This project was continued without change. The crop was small but both McIntosh and Wealthy continue to do better on the mulched plots. The practice of mulching continues to increase in favor among fruit growers. The limiting factor is the cost and scarcity of suitable mulching material.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw.) This project was continued as in previous years. A subsoil plow was drawn through between the plots to minimize the danger of root trespass. Determinations of potash content of the leaf petioles by the Thornton test were made. These agree generally with those made in previous years. The growth of the tree is negatively correlated with the amount of leaf burn and notes of this were taken. Leaf burn is not closely correlated with potash deficiency.

The trees bore a scattering crop. The bearing trees showed little relationship with fertilizer treatment. Because of the narrow plots and crowded condition of the trees it will be necessary to remove these trees in the near future.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw.) No new tendencies appeared in this orchard but the trees, especially on the plots without nitrogen, are not performing well. The variety Wealthy requires better cultural conditions and it is planned to introduce a system of partial cultivation in place of sod culture.

Study of Varieties of Fruits. (J. K. Shaw and staff.)

Apples. There is little to add to the comment made in recent reports concerning new varieties. There are about 75 under test.

Haralson fruited for the first time and proved to be a large, attractive apple except for rather dull red color.

Kendall has not fruited here, but specimens from a southern Vermont orchard proved disappointing in flavor. Further observations are necesssary before its quality when grown in New England can be compared with its quality when grown at its place of origin.

The red sports continue to receive increasing attention and are found in greater numbers in nurseries each year. It is apparent that not all red sports of a given variety are alike. As they cannot be told apart by the nursery trees there is likely to be confusion in buying trees. The Red Spy and Red Gravenstein commonly sold by nurseries seem to be of the strains sent out by the New York Fruit Testing Association. There are various red strains of Delicious under propagation and it is important that the grower be sure just what strain he is getting.

The "Yellow Delicious" offered by many nurseries cannot be distinguished in the nursery from Golden Delicious.

Pears. Cayuga seems promising as a larger pear of the Seckel type.

Plums. Imperial Epineuse from Geneva produced the first real crop this year. It is yellowish-green in color and not particularly attractive but is of excellent quality. It promises to be a desirable variety for the home garden and local trade.

Peaches. The peach variety orchard produced a good crop and observations confirmed previous reports on the varieties grown. Twelve varieties of apricots from South Dakota were put out for trial.

Grapes. Erie, from its performance this past season, promises to be a desirable early blue grape. It ripens about the third week in August, has large berries with an attractive bunch, and is very good in quality.

Fredonia is a desirable substitute for Moore's Early in that it ripens at about the same time and is superior in quality, type of bunch, and production.

Raspberries. Marcy appears superior to Taylor in quality and production.

Indian Summer again failed to mature the fall crop. Many numbered seedlings have been discarded because they appeared to be worthless. Those which show any promise have been retained for further observation.

Sodus, the new purple raspberry from Geneva, appears to be superior to any variety of this type grown here.

Strawberries. Catskill was one of the outstanding varieties in the plantation this year. It surpassed Howard 17 in production. The berries were large and were firmer and more attractive in the basket than Howard 17. It appears to be the best variety for this section that has been produced at the Geneva Station.

Dorsett, while superior in quality, size, and attractiveness, has some faults that limit its value as a commercial sort. It is not a heavy producer even when grown under the spaced row system and the late berries tend to be poorly formed. It is an excellent variety for the home garden.

Fairfax is similar to Dorsett in many respects. It is less tart and retains size better but because of its dark color is less attractive. It is a good variety for the home garden when a mild berry is particularly desired.

Thompson Late is unquestionably the latest variety ever grown here, but the plants and fruit are exceedingly unattractive. The leaves of the plants tend to roll up and the berries are rough and light in color. The quality is only fair and production is good but not exceptional.

Chesapeake is an old variety but is mentioned here because it is a late berry that is attractive and has good quality. In these two respects it surpassed any late variety that has been grown here. Production is relatively low however.

Pathfinder (New Jersey 35) is a new variety from New Jersey that ripens in early midseason, is medium or above in production, and is very attractive. However, the quality is only fair and the berries tend to be somewhat soft. Further observations on this variety are necessary in order to determine its real worth for Massachusetts conditions.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter.) To study further the effects on fruiting of CO_2 in the soil and to provide a check on the results of 1935, eight plots of 87 parent plants each were established in 1936. To eliminate complications arising from a varying stand of plants each parent plant was allowed to form two runner plants only. Four plots were fertilized with two pounds each of dextrose on August 3, August 15, and September 3. The other four plots were not treated. The crowns of all the plants were damaged by cold in the autumn of 1936.

These plots were harvested in 1937. The treatments resulted in a slight reduction in yield.

To study the possibility that winter injury might be responsible for continued failure to get a response to differential soil treatments, 24 plots were established in the spring of 1937. The following treatments were made, each replicated four times.

1.—No mulch.
2.—Light mulch applied early.
3.—Light mulch applied late.
4.—Light mulch applied early, more mulch applied later.
5.—Heavy mulch applied early.
6.—Heavy mulch applied late.

Bud Mutations. (J. K. Shaw and W. H. Thies.) The observations on the scattering crop are but a repetition of those made last year. Some of the grafts supposed to be from mutating trees or branches of trees differ little, if at all, from the original variety, but two or three are distinct sports.

Storage of Apples Under Various Conditions. (O. C. Roberts cooperating with Agricultural Engineering Department.) For several years this Station has investigated the problem of McIntosh storage. Previous results have indicated that

McIntosh that are held for a short period at 45° F. after harvest before being cooled to 32° F. develop a better flavor than similar apples held at 32° F. continuously, and will hold in marketable condition until January 1 or later. A repetition of this work during the past season confirms the results of previous years.

Tests of Various Spray Materials. (O. C. Roberts cooperating with Departments of Entomology and Botany.) This project of testing spray materials was continued during the past season. Each year a multitude of new materials appear on the market together with various recommendations, chiefly by manufacturers, for the mixing and combining of established preparations. These numerous possibilities tend to confuse rather than assist the fruit grower. Hence, the purpose of these spray tests each year is an attempt to measure the real worth of those materials and combinations which appear to merit consideration. A discussion of the materials tested this year together with results obtained may be found in the report of the Entomology Department.

Elimination of Arsenic and Lead Residues from Apples. (O. C. Roberts cooperating with Entomology Department and Fertilizer Control Service.) Since 1925 when the Federal Government placed a limit of tolerance for arsenic on apples, the fruit-growing industry has been concerned with the elimination of residue. Results of previous work at this Station have shown that adherence to the recommended spray schedule for Massachusetts will produce fruit that is practically free from insect and disease blemishes and at the same time is within the limits of tolerance of .018 gr. per pound for lead and .01 gr. As_2O_3 per pound for arsenic. With the possible reduction of the tolerance for lead it is conceivable that the present spray schedule might leave deposits of lead in excess of the lower tolerance. With this possibility in mind experiments on methods of removal were begun in 1934. This work has been continued this year with McIntosh and Cortland apples which received a complete spray schedule. Several bushels of each variety were wiped on a commercial wiper and similar lots of each were washed in a one percent solution of hydrochloric acid. Samples were taken from each lot before and after treatment and were analyzed for lead and arsenic residues by the Fertilizer Control Service. The results of the analyses are shown in the following table.

	McINTOSH		CORTLAND	
	Lead	Arsenic (As_2O_3)	Lead	Arsenic (As_2O_3)
Untreated...	.009	.0033	.019	.0065
Wiped......	.011	.0044	.021	.01144
Washed.....	.003	.002	.002	.00077

These results are consistent with those obtained in previous work at this Station, and show that wiping tends to increase the arsenic and lead residues rather than decrease them and that washing in a one percent solution of hydrochloric acid is an effective method of reducing these residues well within the limits of tolerance.

The Nutrition of the Highbush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) Blueberry Plot D which is to be used in connection with the nutrition work, bore its first crop in 1937. The experiments started in 1936 to test various chemicals as acidifiers for blueberry soil were continued in 1937. On May 21 one gram of nitrate of soda was added to each plant. This fertilizer greatly increased the growth of the plants but at the end of the season the relative position of the various treatments was essentially the same as in 1936. For this reason, no change is necessary in the statements made in 1936 concerning the various treatments.

The study to determine the cause and the cure for chlorosis of cultivated blueberries, which was started in 1935, was continued in 1937. A progress report covering this work will appear in the *Proceedings of the American Society for Horticultural Science* for 1937.

Blueberry Culture. (J. S. Bailey.) The study of the self-pollination of the cultivated blueberry was continued in 1937. A report covering the results of this work from 1935 to 1937 will appear in the *Proceedings of the American Society for Horticultural Science* for 1937. Experiments were started to determine the effect of Gamma (Indole-3)-n-butyric acid on the rooting of blueberry cuttings. This material was tried on dormant cuttings at concentrations of five, ten, and twenty milligrams per hundred cubic centimeters of water for twelve, twenty-four, and forty-eight hours at each concentration. Dormant cuttings showed little or no response when treated for twelve or twenty-four hours at any of the three concentrations. Treated for forty-eight hours, all three concentrations appeared to be toxic. Green wood cuttings taken in July just as secondary growth started were treated for twelve and twenty-four hours with solutions and concentrations of five and ten milligrams per hundred cubic centimeters of water. There appeared to be a slight stimulation of rooting in those cuttings treated for twenty-four hours at a concentration of ten milligrams per hundred cubic centimeters.

For several years blueberry Plot A has been handled under a mulch system, using sawdust and shavings for the mulch. There has never been any indication of mice working in this mulch. In the summer of 1937, Blueberry Plot B was mulched with a heavy coating of waste hay. In October there was ample evidence of a heavy infestation of mice, although this plot is surrounded by plowed land on which a cover crop of buckwheat was grown. This difference in the preference of mice for the two types of mulch may be an important consideration in the mulching of blueberry fields in sections where mice are prevalent.

A row of Jersey plants in Plot C bore their first crop this year. This variety looks very promising. The berries were large, very attractive, firm, and of excellent flavor when well ripened This variety seems to tolerate a drier soil than most other varieties. The variety Pioneer was rather disappointing in its performance in 1937 because the berries tended to drop off considerably in size at the end of the season. The variety Cabot apparently needs picking oftener than other varieties since it has much more of a tendency to drop as soon as ripe.

Premature Dropping of the McIntosh Apple. (L. Southwick.) Work on this project was continued in the light of certain conclusions derived from last year's data. It was found that a study of the total population (entire crop) of a tree gave more significant results than a study of any one particular section of that tree. This possibly is explained by variations between different branches.

This past summer variable fertilizer treatments including direct limb injections were initiated. Also a precise dropping record of numbered apples on three McIntosh trees was kept. Percentages of dropped fruit will be computed, as in years past, for each McIntosh tree in the Station Orchards. The year 1937 will go down as one with heavy drop.

The most significant finding to date is the correlation of time of dropping with fruit seed number. As a general rule, the early drops contain fewer fully developed seeds than those apples that hold on. This seems to hold true for short time durations, even a few days. There is also inconclusive evidence pointing to the probability that fruit shape may have an influence. Undoubtedly many other factors are directly or indirectly associated with pre-harvest dropping of the McIntosh apple. It is hoped that this investigation will eventually produce concrete findings some of which may be applicable to a practical approach to the problem.

Coloring Apples. (R. A. Van Meter, O. C. Roberts, and G. G. Smith.) The fact that sunlight is an essential factor in the production of red color on apples has long been recognized. Consequently apples that are shaded by dense foliage will not color. A well-colored apple is worth at least twice as much as a green one. Therefore, if a practical method of exposing green apples to sunlight after they are harvested could be developed, a higher percentage of the crop would sell at top price.

That apples exposed to direct sunlight soon after harvesting will develop additional red color is an accepted fact. However, apples thus exposed frequently develop a severe case of sunburn. How, then, may the benefits of coloring be obtained without the development of sunburn? In an attempt to find an answer to this question four bushels each of green and partly colored McIntosh were selected. One bushel from each lot spread out in a single layer was exposed under one thickness of cheesecloth, another bushel under two layers of cheesecloth, a third bushel was exposed to direct sunlight, and the fourth bushel was placed in 32° F. storage for future comparison.

Due to cloudy weather the apples were in the coloring frame for six days (September 9 to 16). During this period there were 30 hours of bright sunshine with an average mean temperature of 60°. As a result of this exposure the green apples acquired at least 50 percent color and some specimens which were turned during the period of exposure showed as much as 90 percent color. The increase in color in the case of apples that were partly colored before exposure was marked but not as pronounced as in the case of the green apples.

As the apples were removed from the coloring frame they were placed immediately into 32° F. storage. Examination of these apples on December 31 indicates that the coloring process did not materially impair their keeping quality. Apples that were not covered with cheesecloth developed a sunscald on practically every apple. Shading the apples with one layer of cheesecloth eliminated sunscald on 95 percent of the specimens. Shading with two layers of cheesecloth eliminated sunscald completely. Apples shaded with two layers of cloth colored as well as those shaded with one layer.

DEPARTMENT OF POULTRY HUSBANDRY

J. C. Graham in Charge

Broodiness in Poultry. (F. A. Hays.) The three major objectives in this project are: (1) To secure adequate data on the inheritance of degrees of broodiness, (2) to study the problem of deferred broodiness, (3) to develop a genetically non-broody line of Rhode Island Reds.

To produce the generation hatched in 1936, one aged tested male was mated to nine females, some tested and some not tested. This mating was unsuccessful because of the sexual regression of the male. A second pen of eight females was mated to a yearling male. From this mating three families of daughters consisting of 27 individuals were housed for a trapnest record. Only one family of 7 daughters showed complete absence of broodiness for the first laying year. A second family of 10 daughters showed 2 broody and 8 non-broody. The third family had

3 broody to 1 non-broody. These limited data show typical results from mating individuals that are genetically untested for broody genes.

The present generation hatched in 1937 was sired by two yearling males with a non-broody heritage, mated to yearling, two-year-old, and three-year-old hens with non-broody records. This generation of 100 daughters will furnish data on the question of deferred broodiness.

Breeding Poultry for Egg Production. (F. A. Hays and Ruby Sanborn.) Selective breeding has been carried on in an effort to increase the number of eggs laid and at the same time to improve the flock in body weight, in rate of chick feathering, and in plumage color and to eliminate such undesirable characters as small egg size, light egg-shell color, mottled ear lobes and lopped comb. Another major objective has been to reduce variability in annual egg production.

The last generation of birds shows the general progress that has been made in the experiment. Broodiness stood at the low figure of 4.35 percent of the birds. The mean annual egg production was 234.5. The mean length of winter pause has fallen to 10 days, winter intensity has not changed, persistency has increased from 337 to 351 days — all in comparison with the previous flock. The mortality for a full year in the laying house without culling was 15.95 percent.

In order to test the mode of inheritance of a number of characters being studied, crosses with outside stocks are constantly being made. The results obtained in this project, however, are measured on the pure strain of Rhode Island Reds that has been carried since 1913.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn.) Data have been tabulated and prepared on eight years' work on the inheritance of egg size and external shell characters and published as Station Bulletin 344. Data on body weight in relation to egg production characters, factors affecting fertility, and the relation of time interval between clutches and fecundity are in preparation for publication.

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) Some progress has been made in developing an exhibition line for color alone and another line with exhibition quality combined with the characters essential to high fecundity. Progress is hampered by the necessity of working with small units.

Rate of Feathering in Rhode Island Reds. (F. A. Hays.) The generation hatched in 1937 showed 37 percent of the males to be early feathered in the rapid feathering line and none to be early feathering in the slow feathered line. The wide family variability in the early feathered line indicates that female breeders should be carefully selected from those families with the highest percentage of early feathered males in order to make rapid progress in fixing early feathering in the flock. No relation between rate of feathering and fecundity characters has been discovered thus far.

Breeding for Low Mortality. (F. A. Hays.) Two lines are being developed with respect to mortality rate in the laying houses. The sole basis used in selecting is the mortality rate during the first year of laying. The high and low mortality lines have been carried through three complete generations. Mortality rates in the high line were 40.0 percent, 24.2 percent, and 16.7 percent. In the low line the rates through three generations were 39.5 percent, 0 percent, and 10.3 percent. Annual egg production of the survivors was higher in the low line than in the high line for two generations and equal in the two lines in the third generation. Selective breeding appears to have produced a significant difference in the mortality rates of the two lines.

Time of Emergence of Chicks from the Shell as a Factor in Poultry Breeding. (F. A. Hays.) Records were obtained this year on the time of emergence of 1982 chicks from the shell. Observations were made at eight-hour intervals beginning with the end of the twentieth day. Only one chick emerged at the end of the twentieth day and a relatively small percentage during the first third of the twenty-first day. The greatest proportion of the chicks emerged during the last third of the twenty-first day and the first third of the twenty-second day. A few chicks did not emerge until the last third of the twenty-second day.

These preliminary data show no significant relation between time of emergence and sex, mortality rate, or body weight of pullets at 170 days of age.

Relation of Plumage Color to Sex in Rhode Island Red Chicks. (F.A. Hays.) A total of 3200 pedigreed Rhode Island Red chicks has been described for brown and black pigment spots or stripes on head, neck and back. The value of such pigment areas as an indicator of sex at hatching has not been determined. The relation of this early pigmentation to adult plumage color is being studied.

SEED CONTROL SERVICE

Philip H. Smith in Charge

Seed Inspection. (F. A. McLaughlin and Jessie L. Anderson.) From October 1, 1936 to December 1, 1937* the Seed Laboratory received and worked 2220 samples of seed, of which 874 were collected by the State Commissioner of Agriculture, 1173 were sent in by seedsmen and farmers, and 173 by the American Can Co. for cooperative research.

Classification of these samples with the total number of tests involved is shown in the following summary. It will be noted that the total number of tests required for the 2220 samples was 3080; 769 for purity and 2311 for germination:

Samples		Purity	Germination
421	Field Crops for Purity and Germination	421	421
89	Field Crops for Germination		89
94	Lawn mixtures for Purity only	94	
151	Lawn mixtures for Purity, Germinations involving 439 ingredients	151	439
1228	Vegetable seeds for Germination		1228
103	Flower seeds for Purity	103	
90	Flower seeds for Germination		90
20	Tree seeds for Germination		20
24	Tobacco seeds for Germination		24
2220		769	2311

Field tests to determine trueness to type were conducted in cooperation with the Departments of Vegetable Gardening and Floriculture, the former testing 168 samples of Vegetable seeds and the latter 103 samples of Flower seeds. All samples for these tests were collected and submitted by the State Commissioner of Agriculture.

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*Laboratory year formerly from October 1 to October 1—changed to correspond with fiscal year beginning December 1.

Miscellaneous Work. (F. A. McLaughlin and Jessie L. Anderson.) The Seed Laboratory received 1115.4 pounds of unclean onion seed from Connecticut Valley Farmers, which were returned as 671.3 pounds of clean seed.

Eighty-three samples of corn, oats, barley, and wheat, purchased by various state institutions, were examined for conformity to grade purchased; and twenty-four samples of ground cattle and poultry feed collected by inspectors or sent in by dealers and farmers were examined microscopically.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint, and M. K. Clarke.)

1. *Pullorum Disease Eradication.* During the 1936-37 testing season, a total of 311 flocks (including four flocks of poultry other than chickens) representing 463,095 samples (including 1,333 from fowl other than chickens) was tested. Among the samples submitted from fowl other than chickens 488 were tested with a paratyphoid antigen. Blood samples were submitted from chicken flocks in 11 counties. Norfolk, Worcester, and Middlesex Counties led in the number of tests. The testing results showed increases in tested flocks (55), tested birds (118,860), tests (117,681), and non-reacting flocks (51) over the previous season. The average percentage of positive tests among the total samples tested was 0.37. In only two counties the percentage of positive tests exceeded 0.5 of 1 percent. Pullorum infection was detected in six flocks which were negative to the macroscopic tube agglutination test the previous year or years. In four of these flocks no explanation for the origin for the infection was obtained.

The results show that Massachusetts poultrymen are making progress in pullorum disease eradication and in maintaining their flocks free from the disease. The results show that a total of 281 non-reacting flocks, representing 424,431 birds, were detected. The number of birds in the non-reacting flocks represented 94.6 percent of the total birds tested. The number of birds in the 100 percent tested flocks was 378,563, which represented 84.4 percent of all birds tested. A total of 162 flocks tested for three or more consecutive years, representing 326,435 birds, revealed less than 0.1 of 1 percent infection.

During the past year a turkey flock infected with pullorum disease was subjected to agglutination tests at four-week intervals. Four tests were applied and significant reactors were detected only on the first test. *S. pullorum* was isolated from reactors detected on the first test. No evidence of pullorum infection has been obtained in progeny raised from the tested breeders.

The pullorum disease testing results show that Massachusetts flock owners have available within this State known pullorum clean stock from which replacements can be purchased to establish additional pullorum clean flocks.

2. *Diagnostic Service.* The laboratory received 472 consignments of specimens for examination. Personal delivery of specimens was made 288 times. The classification of 2,264 specimens examined is as follows: 1,944 chickens, 184 turkeys, 72 pheasants, 16 fecal samples, 10 ruffed grouse, 7 bovine, 6 ducks, 5 rabbits, 4 foxes, 4 quail, 4 sheep, 3 deer, and 1 each of canine, hog, horse, mink, and pigeon. Tumors, infectious bronchitis, pullorum disease, fowl paralysis, and coccidiosis were the diseases encountered most frequently. Fowl cholera and fowl

typhoid were detected on more premises than the previous year. Fowl cholera was identified on eight premises of which six represented new foci of infection, whereas fowl typhoid was diagnosed on four premises all of which represented new foci. Fowl typhoid in turkeys was encountered once. Paratyphoid infection was diagnosed once in chickens and three times in turkeys. From one turkey flock 51 dead embryos were cultured and no paratyphoid was isolated. One case of avian tuberculosis was noted.

3. *Flock Mortality Studies.* Morbid and dead specimens were necropsied from two flocks.

Flock A. Among 765 pullets placed in the laying houses in September, 1936, the mortality was 122 birds (15.95 percent) of which 106 (86.88 percent) were submitted to the laboratory during the first laying year or from September, 1936, to October, 1937. As in former years the peak mortality in this flock was reached from March to July, inclusive, when 62 birds (58.49 percent) were received. Of the 106 birds examined, two were decomposed and no diagnosis was made in 14 (13.21 percent). Twenty-four disease conditions were observed among the specimens submitted. Reproductive disorders 22 (18.33 percent), kidney disorders 21 (17.50 percent), cannibalism 14 (11.66 percent), and tumors 13 (10.83 percent) represented 58.33 percent of the total diagnoses.

Flock B. On October 1, 1936, the flock consisted of 694 pullets. Examinations were started November 1, covering a 13-months period to December 1, 1937, and including 308 birds or a mortality of 44.38 percent. The season of peak mortality was longer than in Flock A, extending from February through August, and included 221 birds (71.75 percent). Of the specimens submitted, eight were decomposed and six were recorded as "no diagnosis". A total of 39 disease conditions was observed among the specimens. Tumors 80 (21.05 percent), fowl paralysis 59 (15.53 percent), kidney disorders 55 (14.47 percent), reproductive disorders 36 (9.47 percent), cannibalism 14 (3.68 percent), gizzard necrosis 14 (3.68 percent), and enterohepatitis 12 (3.16 percent) accounted for 71.05 percent of the total diagnoses. Fowl paralysis and tumors showed a greater incidence in this flock than is usual among birds of this age. The incidence of fowl paralysis continued high until May when the birds were over one year of age. The high incidence of tumors began in March when the birds were nearly one year of age and continued during the period of observation.

4. *Erysipelas Outbreaks in Turkeys.* Disease outbreaks due to *Erysipelothrix rhusiopathiae* were observed in three widely separated turkey flocks at approximately the same time of the year. This disease among turkeys has been reported previously only twice in this country. Affected birds may exhibit very pronounced and striking pathologic changes. Erysipelas infection in adult turkey flocks may cause serious losses in the form of mortality, retardation in growth, and less profitable marketing of carcasses for food consumption. The results of the field and laboratory studies have been submitted for publication in the *Journal of the American Veterinary Medical Association.*

5. "*Epidemic Tremor*" *in Chicks.* During the past year "epidemic tremor" investigations have been continued. Chicks hatched at the laboratory from breeding stock which survived the disease did not exhibit symptoms of "epidemic tremor". The disease was transmitted from spontaneous field cases to experimental chicks by means of intracerebral inoculations with saline-brain suspension. The disease-producing agent has been maintained in chicks through 34 serial passages. Filtration experiments have demonstrated that the cause of the disease is a filtrable agent. The disease was not transmitted from inoculated infected chicks to uninoculated chicks through cohabitation. Chicks hatched

from eggs inoculated with saline–brain suspensions prepared from affected chicks developed the disease. Birds eight to ten weeks old, inoculated intracerebrally with saline-brain suspension prepared from affected chicks, developed the disease. This disease is of economic importance to the chick industry and studies are being continued to determine the source or reservoir of the disease-producing agent in order to develop possible methods of control and prevention.

6. *Feeding of Sumac Fruit to Chickens.* Since wild birds utilize sumac fruit as one source of feed, an effort was made to determine the palatability and toxicity of this fruit when fed at will and by means of force feeding. Four chickens, approximately six months old, and the fruit of the staghorn sumac (*Rhus typhina*) were used in the feeding trials. Force feeding of 16 grams of ground sumac per day for five days did not appear to have a toxic effect. Using a mixture of ground sumac fruit and laying mash and permitting the birds to eat at will, resulted in little or no feed being consumed, which suggested that the sumac was not palatable for birds employed in this experiment. This investigation was conducted in cooperation with the Department of Forestry.

7. *Viability of S. pullorum.* Viability studies, which are still in progress, have shown that *S. pullorum* has remained alive in a dry piece of cloth for a period of five years.

8. *Farm Department Brucellosis Control and Eradication.* The laboratory cooperated in this work by testing 878 bovine blood samples for Bang's disease and 52 porcine blood samples for Brucella infection. The standard tube agglutination method was used.

Studies of Neoplastic and Neoplastic-like Diseases. (Carl Olson, Jr.) Various investigations of fowl leukosis, fowl paralysis, lymphocytoma and other neoplastic-like diseases of the domestic chicken are under way. One object of these researches is to seek the similarities or dissimilarities of these diseases from a biochemical point of view by means of a study of the tissue respiration, which it is hoped may be of considerable value in the understanding of these disease processes. Another sphere of activity has to do with a study of the relative incidence of various types of neoplasia among chickens selected from various sources.

Two strains of transmissible fowl leukosis are being maintained and studied. One of these strains originated with material obtained from Dr. J. Furth, Department of Pathology, Cornell University Medical College, New York, N. Y.

The other strain of transmissible fowl leukosis was derived from a poultry flock in Massachusetts where several instances of the disease had occurred. This flock was composed of 47 chickens, among which there were no losses from disease until they were 110 days of age. During the succeeding two months seven birds became ill and died with either fowl leukosis or neoplastic disease. Two of these instances of fowl leukosis were demonstrated to be transmissible to experimental chickens and the transmissible agent has as yet produced only transmissible fowl leukosis. Two cases of neoplastic disease with tumors of the visceral organs have been used as a source of material for the inoculation of experimental animals. One of these tumors has been transplanted into a third generation of the experimental chickens, which procedure has as yet induced no instances of fowl leukosis. The transmissible strains obtained from this flock must be carried through many more experimental chickens before it is possible to tell whether only one or more than one disease-producing agent was responsible for the outbreak of disease noted in the flock selected for study.

WALTHAM FIELD STATION
(Waltham, Massachusetts)

Ray M. Koon in Charge

For reports on approved projects conducted at this Station, in addition to those listed under this caption, see reports of the Departments of Botany, Entomology, Floriculture, Horticulture, and Olericulture.

Consultation and Information Service. The strategic location of the Waltham Field Station makes it possible for a majority of the intensive farmers of the State to reach this Station within an hour by automobile. As most growers realize that a personal call is much better than a letter or telephone call, they come to the Field Station with their problems even during their busiest season. This makes it necessary for the research men to give a considerable part of their time for consultation. Professor Dempsey, appointed two years ago to relieve the research men of this growing activity, has not even been able to take care of the increase. Fortunately, the addition of Professor Graves to the staff as nurseryculturist has spread the work somewhat. It is hoped that the proposed addition of a service in turf-culture will relieve the research men of a number of inquiries concerning turf diseases and insects, and grass soil analyses.

Groups meeting at the Field Station during the year include the Boston Market Gardeners Association, the New England Greenkeepers Association, Rural Electrification Agents of the New England Power Company, New England Carnation Growers Association, the New England Plant Pathologists, the Boston Gardeners and Florists Club, and the Boston Branch of the National Gardeners Association.

Commercial growers and others seeking horticultural information made over 4000 telephone calls. Visitors to the number of 4204 came to the Field Station during 1937. The ornamental display and test gardens attracted 3156 visitors during the growing season.

Field Day. The Nineteenth Annual Field Day was held on August 4 with an attendance of over 1200 The following vegetable contests were held: Celery, Bunched Carrot, Pepper, Trellis Tomato, Bunched Beet, and Summer Squash. Although it seems impossible to increase the number of entries in these contests, the quality of the vegetables entered is second to none.

Soil Testing Service. (Paul W. Dempsey, Harold E. White, Robert E. Young.) The total number of samples of soil submitted for testing was nearly double that of last year.

Summary of Soil Tests

Greenhouse:	
Flowers	657
Vegetable	237
Market Gardeners	785
Miscellaneous*	2397
	4076

*Includes flower gardens, vegetable gardens, lawns, golf courses, landscape gardeners, Metropolitan District Commission, and Highway Beautification.

Seedsmen's Variety Trial Days. (Paul W. Dempsey.) The New York Experiment Station and Cornell University have for a number of years held special meetings for those interested in vegetable varieties. As these meetings are now held every two years, an invitation to look over the variety trials at Amherst and Waltham this year was accepted by over 70 seedsmen and Experiment Station workers. The interest shown would seem to indicate that such a meeting might well be repeated in Massachusetts every four years.

PUBLICATIONS

Bulletins

339 Annual Report for the Fiscal Year Ending November 30, 1936. 100 pp. March, 1937.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

340 Historical Trend in Massachusetts Industries, 1837-1933. By David Rozman and Ruth E. Sherburne. 31 pp. January, 1938.

In Massachusetts as in many other states, there have occurred over a period of years shifts in population and in the distribution of industries between individual cities and towns of various sizes. This publication presents a graphic summary of the changes in population, number of industrial employees, and number of industrial establishments during the last hundred years, for those cities and towns of the Commonwealth where the historical data are available.

341 Vacuum-Pressure Relationships in Glass Canning Jars. By C. R. Fellers, A. S. Levine, and W. A. Maclinn. 20 pp. April, 1937.

The present method of canning foods in the all-glass type of fruit jar has several disadvantages, some of which are overcome by a slight change in method of processing. As a result of a two-year investigation of the vacuums and internal pressures in all-glass canning jars during heat processing and of practical cooperative experience involving over 16,500 all-glass jars, 50 canned foods, and 60 home canners, it is considered advisable to recommend sealing the jar by tightening the wire bail previous to thermal treatment (processing). This method decreases markedly the losses of liquid from jars during processing, improves the appearance of the contents, saves time, obviates the necessity of handling the hot jars after processing, and has no effect on either breakage or spoilage.

342 Facts, Fads and Frauds in Nutrition. By Helen S. Mitchell and Gladys M. Cook. 31 pp. April, 1937. (Reprinted in November.)

Present-day food advertisements make a tremendous appeal to a nutrition-conscious public which has only a very limited basis for evaluating the merits of the claims made. This bulletin attempts to present in brief and readable form information, decisions and criticisms by recognized authorities concerning nutritional and therapeutic claims in food advertising as well as faulty concepts and notions regarding foods and nutrition, as a guide to the consumer. Sources of reliable information on foods and nutrition are listed.

343 The Dutch Elm Disease — A New Threat to the Elm. By Malcolm A. McKenzie and William B. Becker. 16 pp. May, 1937.

At the present time the Dutch elm disease is not known to occur in Massachusetts. However, the oldest known American infestation of the principal carrier insect of the disease, the smaller European elm bark beetle, was discovered in the vicinity of Boston in 1909. With this known carrier already well established in Massachusetts, the elms of the State would be in grave danger of destruction should the Dutch elm disease be introduced among them. This bulletin describes the disease and its symptoms, as well as how it is spread, and urges the cooperation of everyone in the efforts being made to protect and preserve the elms.

344 Inheritance of Egg Size and Egg Character. By F. A. Hays. 28 pp. July, 1937.

A study of egg size and egg character, covering nine generations of Rhode Island Reds, is summarized in this report. The data furnish more definite information on the inheritance of egg size, egg shape, shell texture, shell porosity, and shell color, thus making it possible to offer some specific recommendations to poultry breeders.

345 Woody Plants for New England Gardens, Parks and Roadsides. By George Graves. 84 pp. August, 1937.

This is an attempt to evaluate hardy woody plant materials and to summarize expert opinions regarding their adaptability for landscape planting in New England. So far as possible the general idea of evaluation without attempt at dogmatic standardization has been followed through, The plants have been considered for their habit, garden aspect, and cultural behavior, and the resulting data brought into a single treatment.

346 Nitrogenous Fertilizers for Growing Tobacco. By A. B. Beaumont and M. E. Snell. 15 pp. October, 1937.

In the many years that tobacco has been grown in the Connecticut Valley, certain fertilizer practices have come into use. This study was undertaken to provide a research basis for those practices which are considered sound. The study included experiments on quantity and form of nitrogen, ratio of organic to inorganic nitrogen, and method of applying fertilizer. The results indicate that a comparatively high rate of application of fertilizer nitrogen is necessary for growing Havana Seed tobacco of high yield and quality, and that no more than one half and probably as little as one fourth of the nitrogen need come from organic carriers such as cottonseed meal.

Control Bulletins

88 Seventeenth Annual Report on Eradication of Pullorum Disease in Massachusetts. By the Poultry Disease Control Laboratory. 11 pp. June, 1937.

89 Inspection of Commercial Feedstuffs. By Philip H. Smith. 57 pp. November, 1937.

90 Inspection of Commercial Fertilizers. By H. D. Haskins. 48 pp. November, 1937.

91 Inspection of Agricultural Lime Products. By H. D. Haskins. 9 pp. December, 1937.

Meteorological Bulletins

577-588, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By C. I. Gunness. 4 pp. each.

Reports of Investigation in Journals

242 Acid production by the Escherichia-Aerobacter group of bacteria as indicated by dissolved metallic iron. A. V. Syrocki, James E. Fuller and Ralph L. France. Jour. Bact. 33 (2):185-192. 1937.

A preliminary report of a method which it is hoped may be developed as a means of differentiating Escherichia-Aerogenes bacteria, and especially intermediates of the group, on the basis of their acid production from carbohydrates. When employed with pure cultures, the procedure made possible satisfactory differentiation of *E. coli* from *A.aerogenes* and from intermediates of the group, but differentiation of other members of the group from each other was not accomplished.

249 Salmonella infections in chickens. H. Van Roekel and K. L. Bullis. Jour. Amer. Vet. Med. Assoc. 91 (n.s. 44):48-58. 1937.

Pullorum disease is the most widespread of the poultry diseases caused by members of the *Salmonella* genus, and a leading cause of economic loss to the poultry industry. Data presented show that this disease and possibly other Salmonella infections can be eradicated from flocks by the use of the macroscopic agglutination test along with sound eradication measures.

253 Gas content of cranberries and possible relationship of respiratory activity to keeping quality. Wm. B. Esselen, Jr., and C. R. Fellers. Plant Physiol. 12:527-536. 1937.

The carbon dioxide content and the carbon dioxide–oxygen ratio of cranberries vary directly with the keeping quality of the fruit, the rate of respiration, and the temperature. Carbon dioxide–oxygen ratios under 0.7 seem to show that the berries are fairly sound and possess good keeping quality. As the ratios increase above 1.0, the quality of the cranberries becomes poorer and poorer. Freshly picked cranberries show a carbon dioxide-oxygen ratio of from 0.3 to 0.6.

254 Composition and utilization of the Atlantic Whiting, Merluccius bilinearis. D. A. Bean, J. A. Clague and C. R. Fellers. Trans. Amer. Fish. Soc. 66 (1936):415-421. 1937.

Whiting flesh contains approximately 16.6 percent protein, 2 percent fat, and 1.1 percent ash. The liver oil is an excellent source of vitamins A and D, containing 2700 international units of A and 950 units of D per gram. Smoked fillets, either fresh or canned, were considered the most promising whiting product.

257 Nutritive value of chocolate flavored milk. W. S. Mueller and W. S. Ritchie. Jour. Dairy Sci. 20 (6):359-369. 1937.

The effect of the addition of varying percentages of cocoa to mineralized whole milk was studied by means of growth experiments on a total of 72 albino rats. Milk containing 1 percent of cocoa gave results equal in all respects to those obtained with the plain whole milk. When milk containing more than 1 percent of cocoa was fed ad libitum, the rate of consumption decreased as the percentage of cocoa increased; when fed in controlled amounts, the growth of the rats was retarded. Assuming that these results may have some application to human nutrition, it seems reasonable to conclude that the cocoa in average commercial chocolate milk does no harm nor does it enhance the nutritional value of the milk.

259 The relation of ingested carbohydrate to the type and amount of blood and urine sugar and to the incidence of cataract in rats. Helen S. Mitchell, Oreana A. Merriam and Gladys M. Cook. Jour. Nutrition 13 (5):501-511. 1937.

The discovery and repeated confirmation of the fact that lactose and galactose rations may cause cataract in rats has been followed in this laboratory by extensive investigations as to the nature of the metabolic disturbances involved. The present studies into the nature of the blood and urine sugar of rats fed high levels of these two sugars have been made in connection with further observations on factors influencing the rate of development of lens opacities. It may be concluded that galactose is the sugar responsible for both the high blood and the high urine sugars observed in rats fed on lactose and galactose rations and must be the major etiological factor in this type of cataract.

261 A chlorosis of cultivated blueberries. J. S. Bailey. Amer. Soc. Hort. Sci. Proc. 34:395-396. 1937.

Two years ago there appeared in certain portions of plantations of cultivated blueberries at Amherst a chlorotic condition of the plants which seemed to be due to a nutritional deficiency. Affected plants were also found in Hanover and on Cape Cod as well as in New Jersey. Various treatments were tried, but the only one which has so far seemed effective was an application of ammonium sulfate, and recovery took about a year.

263 A genetic study of Tropaeolum. W. G. Whaley and A. P. French. Amer. Soc. Hort. Sci. Proc. 34:598-602. 1937.

The data included in this report have been compiled after observing the results of an interspecific cross between *Tropaeolum majus* var. Golden Gleam (female) and *T. peltophorum fimbriatum* (male) in the F_1 and F_2 generations.

264 Influence of certain fruits on fecal flora and intestinal reaction in diets of rats. William B. Esselen, Jr. Food Research 2 (1):65-72. 1937.

In order to study further the apparent beneficial action of fruit diets for intestinal disorders, work has been carried on to note the effect of cranberry, blueberry, and apple diets on the intestinal flora, putrefaction, and acidity of the albino rat. A 20 percent cranberry diet was effective in reducing the numbers of fecal gas-producing bacteria and *Escherichia coli*. Diets containing 20 percent cranberry, blueberry, and apple materially decreased intestinal putrefaction. Diets of 10 and 20 percent raw cranberry, and of 100 percent raw apple significantly increased the acidity of the contents of the cecum and large intestine.

265 Vitamins A, C, and D in maize as affected by variety and stage of growth. W. B. Esselen, Jr., C. R. Fellers and B. Isgur. Jour. Nutrition 14 (5): 503-511. 1937.

Vitamin A increased with growth of the plant above 25 cm., while vitamin C decreased. There was no correlation between the amounts of vitamins A and C in the plant and the color of the grain. There was a marked loss in vitamin A and moisture after the plants had attained maximum growth. This loss of vitamin A in mature corn fodder is a factor to be considered in the use of fodder as an animal feed. The grain of yellow maize lost much of its vitamin A as it matured and dried out.

266 Some observations on internal cork disease of apples in Massachusetts. J. S. Bailey and W. H. Thies. Amer. Soc. Hort. Sci. Proc. 34:187-191. 1937.

During the season of 1936, an internal browning of the fruit of certain McIntosh and Cortland trees attracted considerable attention in Massachusetts. Our observations show that this disease is not limited to any one soil type, it occurs where the subsoil is unfavorable for root penetration, and is partially prevented by a heavy mulch. Trees with a shallow root system, from whatever cause, are at a distinct disadvantage in a time of drought. They may be unable to obtain an adequate supply of moisture during a part of the growing season, and it seems reasonable that this would prevent a normal development of the fruit. This association of the disease with water deficiency has been reported by several workers.

267 Tomato variety and strain differences in ascorbic acid (vitamin C) content· W. A. Maclinn, C. R. Fellers and R. E. Buck. Amer. Soc. Hort. Sci. Proc· 34:543-552. 1937.

Ninety-eight distinct varieties or strains of tomato grown under constant field conditions were found to vary in vitamin C content from a maximum of 249 to a minimum of 74 units per ounce. Different strains of the same variety showed marked differences in vitamin C. No correlation was found between size of tomatoes or degree of ripeness and vitamin C content. Data on storage tests indicate that the vitamin C of tomatoes is not seriously affected during shipment, in markets, or at canneries so long as the fruits remain firm and sound.

268 The Fungi of Nantucket. Century I. E. F. Guba. Rhodora 39:367-376. 1937.

Dotted with ponds and bogs and sometimes enshrouded by heavy fogs and storms, Nantucket provides conditions which are especially favorable for a rich fungus flora and for epidemics of plant diseases. It is the hope of the author to make a fairly complete collection of the fungi of these islands and to publish the material in sets of centuries. This paper is the first of the series.

269 A photo-electric Tyndall meter. W. S. Mueller. Food Research 2 (1): 51-54. 1937.

The instrument here described was developed for the purpose of studying the effect of temperature treatments on the light-scattering ability of gelatin sols and gels, where a a need was felt for an instrument extremely sensitive to light intensity.

270 Stability of vitamin C in sweet corn to shipping, freezing, and canning. C. F. Dunker, C. R. Fellers, and G. A. Fitzgerald. Food Research 2 (1): 41-50. 1937.

Raw, fresh-cooked, frozen, and whole-grain canned sweet corn are all moderately good sources of vitamin C (40 to 60 international units per ounce). Cream-style canned corn is a little lower than whole-kernel. Little loss in vitamin C occurs after picking and storage in the husk for a few days. Similarly, frozen corn can be defrosted and canned corn kept in the refrigerator for several hours after opening without appreciable loss of vitamin C.

271 Hatchability as related to seasons and hour of laying. F. A. Hays. Poultry Sci. 16 (2):85-89. 1937.

Under the conditions of incubation used, late hatching increased hatchability for hens but not for pullets. Hour of laying appeared to have no significant effect on fertility, embryonic mortality, or hatchability of fertile eggs.

273 Some milk superstitions. J. H. Frandsen. Jour. Home Econ. 29 (4):242-243. 1937.

The author unmasks some of the old superstitions regarding milk, in the hope that a knowledge of the facts will lead to an increase in the use of one of our best foods.

274 Careful culture recommended to avoid canker on gardenias. Harold E. White. Florists' Review, February 25, 1937.

This paper describes symptoms, the part of the plant affected, possible means of infection, and cultural methods which should keep the disease from becoming established.

275 The precipitation of erythrosin by members of the Coli-Aerogenes group. Ralph L. France and James E. Fuller. Zentbl. Bakt. II Abt., Bd. 97: 312-314. 1937.

It was thought that this reaction to erythrosin might be of value in differentiating members of the coli-aerogenes group; but the present studies did not confirm this.

277 Dextrose in the manufacture of fruit and vegetable products. Carl R. Fellers, Joseph Miller and Thomas Onsdorff. Indus. and Engin. Chem. 29:946-949. 1937.

As a rule crystalline dextrose can be used in most canned fruits and fruit products to the extent of from 20 to 40 percent of the total sugar added. In some cases an improved product resulted. Dextrose is particularly suitable for use in sweet pickles and relishes, candies, and soda fountain syrups.

278 A polyuronide from tobacco stalks. Emmett Bennett. Indus. and Engin. Chem. 29:933. 1937.

The isolation and partial analysis of a polyuronide from the cured stripped stalk of Havana seed tobacco is described. Upon hydrolysis the polyuronide yields xylose as the chief sugar.

279 Influence of protein or cystine intake on cataract-producing action of galactose. Helen S. Mitchell and Gladys M. Cook. Soc. Expt. Biol. and Med. Proc. 36:806-808. 1937.

Ever since it was first demonstrated that galactose causes lens changes in rats, experiments have been under way in an effort to explain the metabolic disturbances involved. The data presented show that a protein deficiency definitely hastens the development of galactose cataract, but leave it doubtful whether cystine is the crucial factor.

280 A study of oiling off of cream in coffee. Herbert Jenkins and Merrill J. Mack. Jour. Dairy Sci 20 (11):723-735. 1937.

The fat emulsion in cream is frequently destabilized to the extent that some of the fat will rise to the surface when the cream is used in coffee, a condition known as "oiling off." A suitable test for measuring the extent to which cream will oil off in coffee has been developed and is described in this paper. Factors which affect the stability of the fat emulsion in cream and therefore have a bearing on the problem of oiling off are discussed.

282 A preliminary study of the relationship between vitamin C content and increased growth resulting from fertilizer applications. B. Isgur and C. R. Fellers. Jour. Amer. Soc. Agron. 29 (11):890-893. 1937.

Preliminary data obtained from pot experiments using New Zealand spinach and Swiss chard show that increases in yield caused by fertilizer application were accompanied by increases in vitamin C content in the case of Swiss chard but not in the case of New Zealand spinach. The high nitrogen treatments resulted in the highest yields of ascorbic acid in the Swiss chard.

284 Oat flour as an antioxidant in ice cream. W. S. Mueller and M. J. Mack. Ice Cream Trade Jour., October, 1937.

Oat flour was found to have antioxidative properties when used in ice cream, the use of only 0.25 percent of oat flour in the mix delaying the development of off-flavors in the ice cream during storage, although 0.5 percent was more effective. Oat flour also has the properties of a stabilizer, and when it is added to the mix a reduction should be made in the amount of other stabilizer used.

288 Browning of Conifers. Malcolm A. McKenzie. American Nurseryman 66 (11):10. 1937.

Brown needles on conifers in autumn result from a variety of causes and may not be of a type that means permanent injury to the trees. An examination of the buds will furnish the best clue as to whether the browning is a natural condition of a healthy tree or is due to some injury. Plentiful firm green buds indicate a healthy tree, while a scarcity of buds or buds with colorless tissue indicate weakened or injured trees.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN 348 MARCH 1938

Control of the Begonia Leaf-Blight Nematode

By E. F. Guba and C. J. Gilgut

The leaf-blight nematode is a major pest of certain winter-flowering begonias in greenhouses in Massachusetts. Affected plants are of inferior sale value or a total loss. This bulletin describes a practical method of control.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

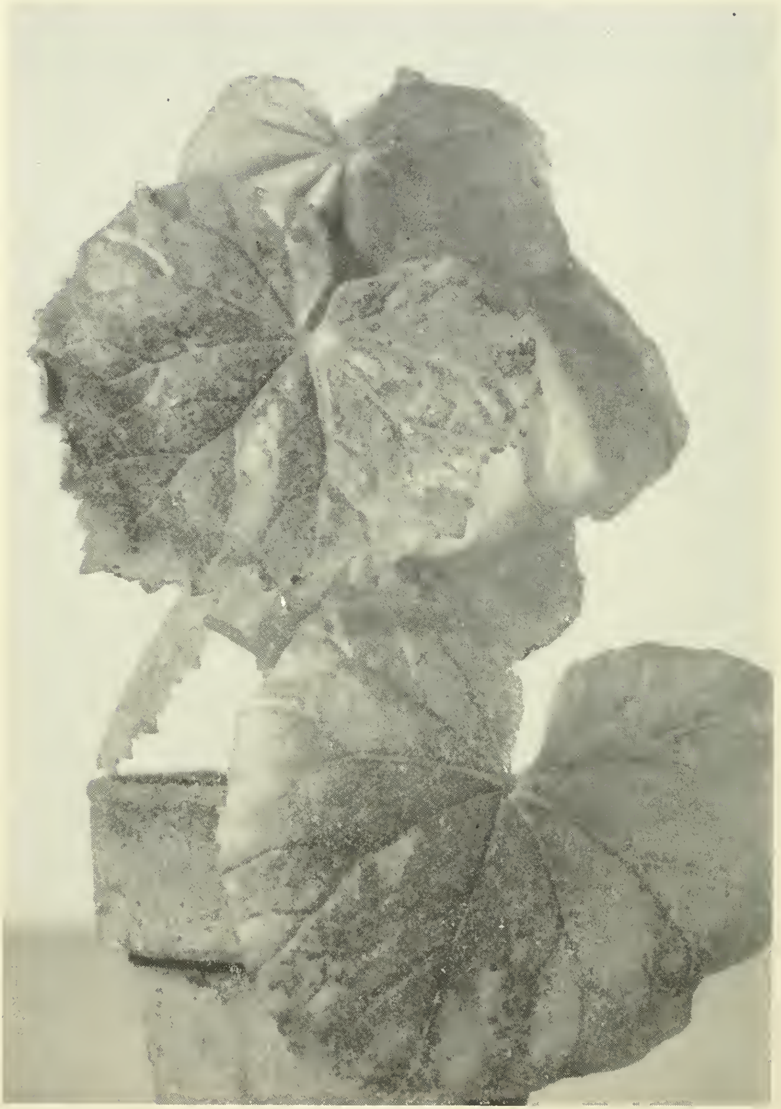

Figure 1. Lady Mac begonia showing the russeting of the upper surface of leaves caused by the nematode Aphetenchoides fragariae (Ritz.-Bos) Christie. The corresponding lower surfaces are of a lustrous dense brown color. Infested leaves ultimately perish.

CONTROL OF THE BEGONIA LEAF-BLIGHT NEMATODE

E. F. Guba, Research Professor of Botany,
and C. J. Gilgut, Research Assistant in Botany[1]

Winter-flowering begonias as represented by such varieties as Melior, Lady Mac, and Marjorie Gibbs are an important floricultural crop in many greenhouses in Massachusetts. The production of these begonias varies from about 500 finished pot plants among the smallest growers to 4,000 among the largest growers and the demand is confined almost entirely to the Christmas holiday season. Some growers also specialize in the production of propagating stock. These begonias are propagated from leaf cuttings in December and January, potted in 2¼-inch pots and then shifted to larger pots with successive periods of growth. The last shift to 5- or 5½-inch pots is usually made in July.

Melior types of begonias are very susceptible to a well-known leaf-blight disease caused by the nematode *Aphelenchoides fragariae* (Ritzema-Bos 1891) Christie 1932. Clinton (4) in 1916 published an excellent illustrated account of this disease on the varieties Cincinnati and Gloire de Chatelaine and designated the nematode as *Aphelenchus olesistus* Ritzema-Bos. The presence of discolored, diseased leaves in the composition of the plant or their repeated removal to improve the appearance of the plant and also as a sanitary measure causes inferior quality, lower sale value and, in bad cases of infestation, a total loss. (Figs. 1, 2.)

HISTORICAL

RECOMMENDED CONTROL MEASURES

A review of the literature on the control of the leaf-blight nematode reveals recommendations that may be grouped into three distinct categories; namely, treatment of begonias with chemicals, cultural practices, and hot-water submersion of infested plants.

The spraying or dusting of begonias with chemical materials is the least worthy of commercial practice because of the danger of injury and, according to several reports, the lack of control. The submersion of valuable plants for one hour each day for a week in water at 64.4° to 68° F. and subsequent spraying, while they are still moist, with a 0.5 to 1 percent solution of amonia has been sugrested, but this treatment is not practical. The water-bath treatment causes the nemas to wander from the leaves. The water treatment and subsequent rinsing in fresh water has been recommended for leaf cuttings before they are placed in the sand bench for rooting, but because these baths do not kill the nematode, the practice would appear to be very unsanitary and an ideal method of dissemination.

Many cultural practices have been suggested; notably, wider spacing to avoid contact with leaves of adjoining plants, careful bottom watering, removal of diseased leaves, and the isolation of infested plants. Propagating from healthy stock is very important. The selection of leaves from healthy plants in stock showing disease is inadequate and ineffective. Aside from the practice of propagating from clean stock, none of the measures mentioned may be considered reliably effective or encouragingly successful in commercial practice because they fail to eradicate the causal organism.

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[1] The writers are gratefully indebted to Dr. J. R. Christie, Nematologist, United States Department of Agriculture, for supplying published articles and literature references and for information pertinent to these studies.

The submersion of infested plants or root stocks in hot water to eradicate leaf nematodes, mites, and other pests has been advocated in the literature, and the treatment would appear to be a very valuable control measure where it can be done safely. There is considerable literature relative to water temperatures lethal to the leaf-blight nematode, *Aphelenchoides fragariae* (Ritzema-Bos) Christie, as well as definite recommendations for treating infested plants with hot water as a method of successfully controlling the organism. Aside from the studies of Marcinowski (9) with the begonia variety Gloire de Lorraine in which good control of the nematode without serious injury is claimed, and the studies of Gill (6, 7) with Melior and Lady Mac, reporting no control without decided injury to the plants, nothing has been reported on the question of tolerance of these begonias to hot-water treatments. The problem, therefore, seemed to justify study.

LETHAL HOT-WATER TEMPERATURES

In view of the confusion in the taxonomy of the organism and the interchangeable use of the specific names, *olesistus*, *fragariae*, *ritzema-bosi* and *ormerodis*, which are associated with diseased conditions in the leaves or crowns of violet, strawberry, fern, chrysanthemum, begonia and many other plants and which some authorities regard as synonymous or merely strains of the same form, a review of pertinent knowledge of temperatures lethal to these nemas on these hosts should be helpful to the understanding of the problem.

Marcinowski showed that when potted ferns or individual fronds still attached to plants were submerged at 122° F. for five minutes or 131° F. for one minute, the treatment was completely lethal to the nematode. These were the lowest time intervals for these temperatures at which kill was complete. In the first instance the condition of the plants remained good. With Gloire de Lorraine, immersion for five minutes at 122° F. caused the old leaves to shed. The new growth subsequently produced strong and healthy shoots. Since the surface of the soil and the pots obviously are populated by the nematode, the immersion of plant and pot was recognized as being essential to the successful control of the pest. Gill found a temperature of 116.6° F. for five minutes lethal to the nematode in begonia leaf tissues and also harmful to the plants. Molz (10) found that in the immersion of bits of infested chrysanthemum leaves for a period of 10 minutes, the lowest completely lethal temperature was 109.4° F., and after immersion for five minutes at this temperature only one active nema was observed. At 113° F. for five minutes, the kill was complete. Steiner and Christie, according to Dodge (5), controlled the nematode on chrysanthemum by immersing roots and crowns in water at 118° F. and 120° F. for 30 minutes, but for growing plants the treatment was not safe. Hodson (8) found that a water temperature of 110° F. for 20 minutes for small stools and 30 minutes for large stools of chrysanthemum was effective. According to Staniland and Beaumont (13), a temperature of 110° F. for 15 minutes was the best treatment for violet runners and over a three-year period caused a marked improvement of the stock. In reports of investigations on control of the strawberry nematode, immersion of stock in hot water is recognized. Brooks (1) recommended a 20-minute submersion in water at 118.4° F.; Christie and Stevens (2) a 30-minute submersion at 118° F.; and Staniland and Beaumont (12) a 15- or 20-minute submersion at 110° F., but later found a 30-minute treatment more efficient and preferable if good planting conditions exist. Christie and Crossman (3) showed that a temperature of 112° F. for 15 minutes and 115° F. for 5 minutes was lethal to the nematode

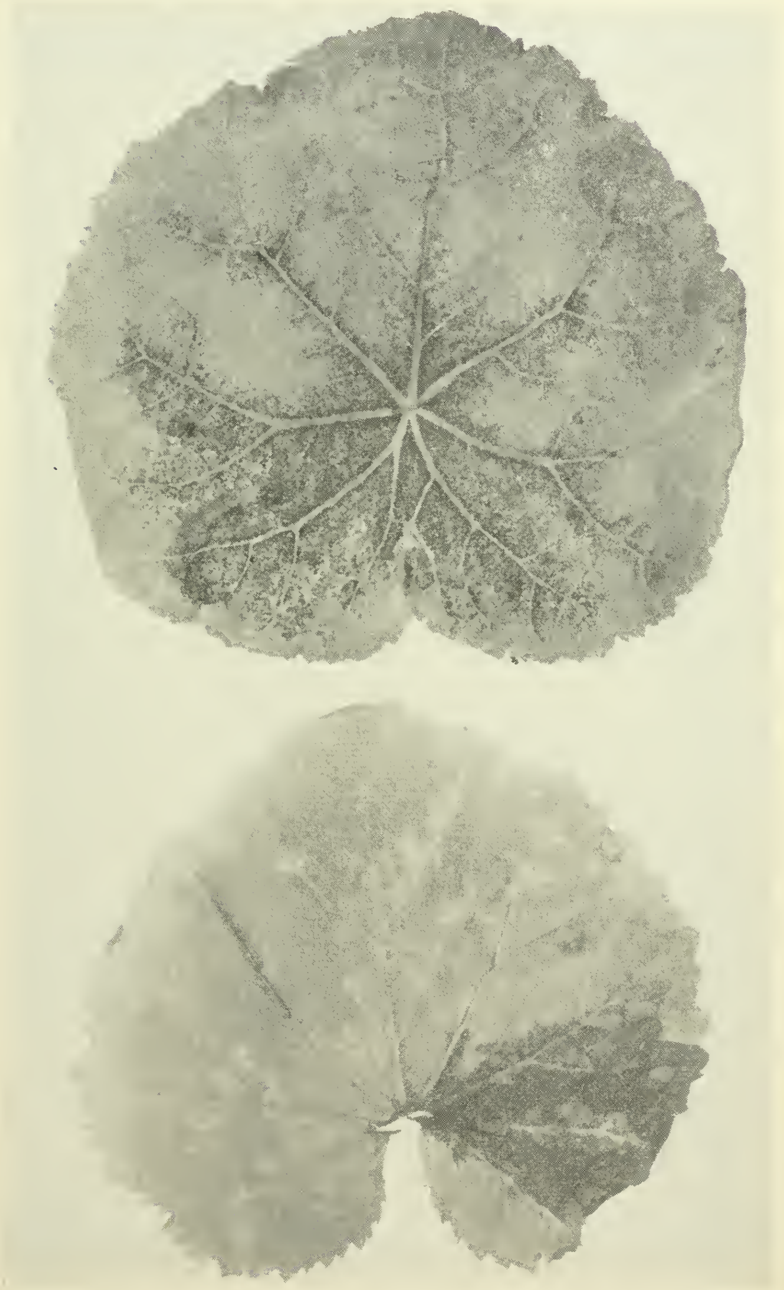

Figure 2. Nematode-infested begonia leaves. A unique and excellent photograph of the disease. Photograph by R. E. Young.

from begonia; 115° F. for 12 minutes was lethal to the nematode from chrysanthemum and 94 percent were killed in 10 minutes at this temperature; 115° F. for 10 minutes and 120° F. for 5 minutes was lethal to the nematode from Cape Cod, Massachusetts, strawberry plants and at 118° F. for 5 minutes 96 percent were killed; and 120° F. for 15 minutes was lethal to the nematode from North Carolina strawberry plants. These conditions were minimum for a completely lethal effect on eelworms in 0.5 cc of water in test tubes. None of the investigators considered treatments of less than five minutes. This appears to be important in commercial practice both from the viewpoint of practical utility and the probability of greater plant tolerance against injury.

EXPERIMENTAL PROCEDURE AND RESULTS

In experiments here reported, entire plants in 5-inch clay pots and pans were completely submerged in water in a tub. The water was first brought to the desired temperature with hot water piped from the water heating system and in the interval of submersion the water was constantly agitated. The temperature at the finish of the submersion period was recorded and the mean of the start and finish temperatures was used in plotting the graph of the results. There is no need for constant water temperature. It would complicate rather than simplify the hot-water treatment in commercial practice. The body of water in the experiments was large enough to keep the temperature during the interval of treatment within a few degrees of the starting temperature.

The effect of the hot-water treatment on the nematode was determined by examining bits of epidermis from the lower surface of infested leaves. The first examinations were made a few days after treatment of the plants. Other examinations were made at later intervals, and final observations in most cases were made more than two months after the treatment. The interval was ample to reveal instances of recovery and the hatching of eggs. Nematodes which survived the treatment were active and turgid. Those showing no motion and wholly or partly collapsed were regarded as being dead. Records were also made of any injuries to the foliage, the shoots and the plants as a whole during the course of observations.

Leaves of the varieties Lady Mac and Marjorie Gibbs were treated with hot water to determine the tolerance and effect on rooting, and hence the practicability of the treatment for leaves gathered for propagation where infestations exist in the mother plants. Both infested and healthy leaves were used in the tests. The leaves were wrapped in cheesecloth and kept submerged in the water bath throughout the interval of treatment. They were then inserted in sand for rooting.

SUBMERSION OF POTTED PLANTS IN HOT WATER

Water Temperatures Lethal to Nematode

The kill of the nematode, both eggs and worms, followed the interval temperature curve shown in Figure 3 corresponding to mean temperatures of 115° F. for 5 minutes, 117° F. for 3 minutes, 118½° F. for 2 minutes, and 120½° F. for 1 minute. No difficulty was experienced in eradicating the organism without causing injury to the plants. The lethal effect of temperature on the nematode appeared to be more constant than the tolerance of the leaves to the treatment, which seemed to indicate a variation in tolerance of individual plants. Christie and Crossman reported a temperature of 115° F. for 5 minutes lethal to the nematode. A temperature of 116.6° F. for 5 minutes reported by Gill deviates but slightly from these results. It is noteworthy that the minimum water temperature lethal to the begonia leaf-blight nematode has been found to be consistent by those who have considered the problem. The wider deviations from these lethal temperatures, noted earlier, suggest the existence of differently acclimated strains or even distinct species. Inaccuracies and variations in technique may also be factors accounting for slight discrepancies in the results.

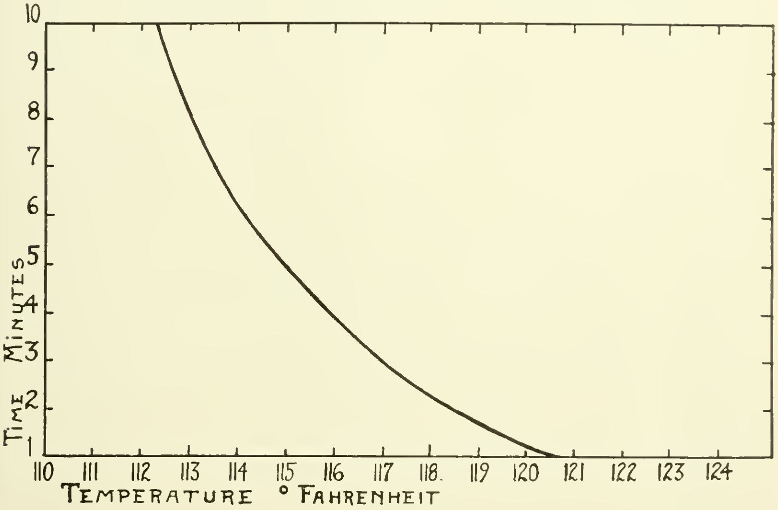

Figure 3. Time required to kill the begonia leaf-blight nematode at different water temperatures.

Tolerance of Plants

In all of the experiments, infested leaves were always injured, more intensely browned, ultimately killed by the water bath, and finally had to be removed from the plants. This was true even though the symptoms of the disease were only slightly evident. The removal of these leaves was necessary to preserve the healthy appearance of the foliage. Such being the case, the practice of pinching off and destroying infested leaves before the hot-water treatment seems preferable and this sanitary practice would be a valuable supplement to the hot-water treatment in the direction of better control. In general, a range of temperature of 123°-120° F. for 1 minute, 118°-115° F. for 3 minutes, and 115°-113° F. for 5 minutes was safe. Some slightly higher tolerant temperatures at these intervals were noted. In addition, frequently the 5-minute treatment appeared to cause some hardening of the foliage (Table 1). At all the temperatures within the 5-minute period of submersion which were lethal to the nematode, except a few of the more extreme treatments, i.e., 124-123° F. for 1 minute, 123-120° F. and 126-123° F. for 3 minutes, and 120-118° F. for 5 minutes, the younger leaves and shoots and the buds were not injured and new growth followed the treatment. Some of the treatments which gave excellent control of the disease without injury are illustrated in Figure 4.

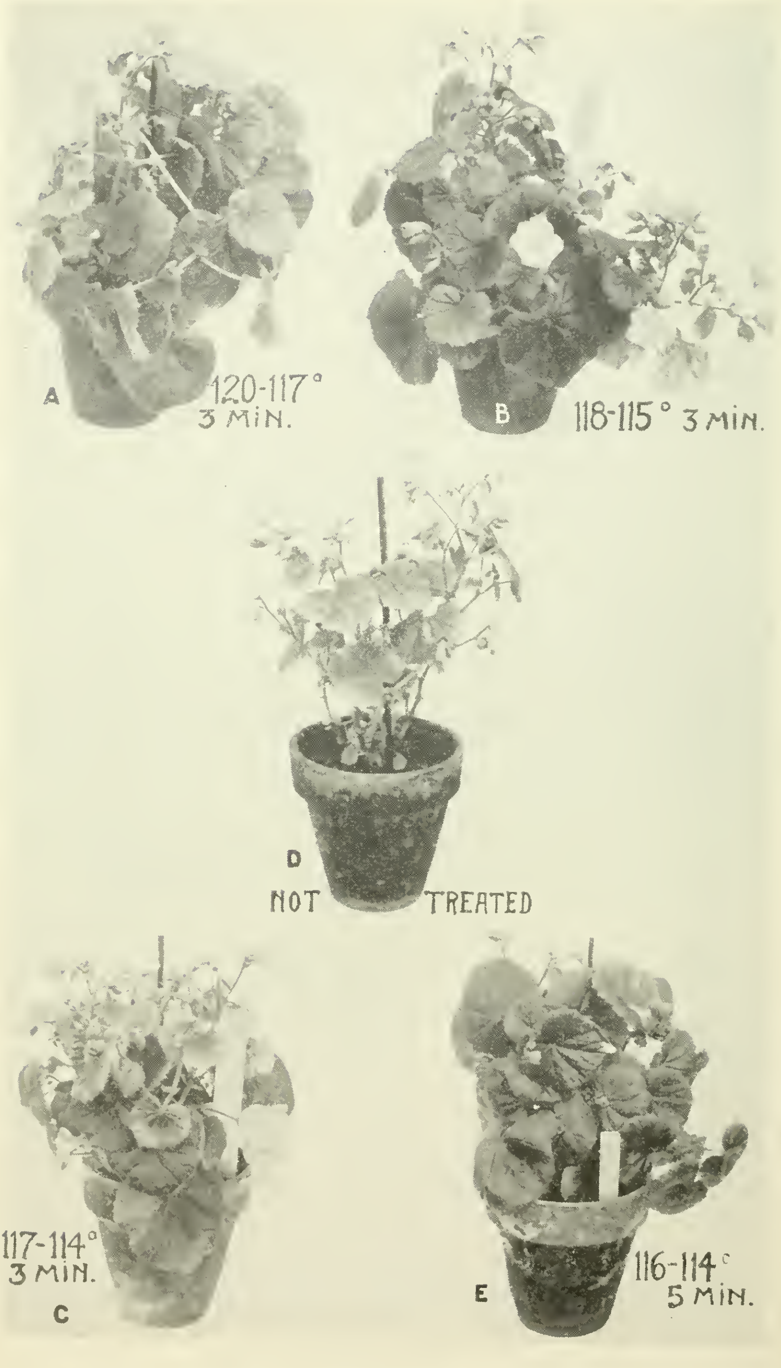
A
120-117°
3 MIN.
B
118-115° 3 MIN.
D
NOT TREATED
117-114°
3 MIN.
C
E
116-114°
5 MIN.

Figure 4. Representative begonia plants treated with hot water.

A and C treated Sept. 20; B. Oct. 4; E. Oct. 7. Infested leaves which were further injured by the treatment were removed after the bath and no more disease appeared.

D, no treatment. Leaves of untreated plants showing disease were removed periodically up to the time of the photograph on Nov. 18. The effect of this practice on the composition and quality of the plant is clearly shown.

Table 1.—Reaction of Begonia Plants and Nematodes to Hot-Water Treatments*

Temperature °F.	Time (Minutes)	Injury to Plants	Survival of Nematodes
121–120	1	None	Very rare; no further disease
121–120	1	Slight burns on few leaves	Very rare; no further disease
122–121	1	None	None
123–121	1	None	None
124–123	1	Badly injured	None
114–112	3	None	No control; further disease
117–114	3	None	Very rare; no further disease
117–115½	3	Infested leaves injured	None
118–115	3	None	Very rare; no further disease
118–116½	3	None	None: no further disease
119–116	3	Slight burns on few leaves	None
119–117½	3	Slight burns on few leaves	None
120–117	3	None	None
121–118	3	Some burns on older leaves; new buds and shoots healthy	None
123–120	3	Badly injured	None
126–123	3	Badly injured	None
114–112	5	None	No control; further disease
115–113	5	Moderate burning on some older leaves	Rare; no further disease
115–113¼	5	Only infested leaves injured	Very rare
115¼–113¼	5	Slight burns on some older leaves	Fair control
115½–113½	5	Only infested leaves injured	None
116–114	5	Slight burns on some older leaves	Very rare; no further disease
116–114	5	Infested leaves burned; slight burning otherwise	None
118–116	5	None	None
120–116	5	Considerable burning; new leaves and shoots healthy	None
120–118	5	Severe foliage injury; new shoots healthy	None
117–115	5	Burning confined to infested leaves	None
113–110¼	7	None	No control; further disease
114¼–112	7	Older infested leaves badly injured; new shoots healthy	Very rare; no further disease
111–109	10	Considerable injury and stunting	No control
113–110	10	Slight burning of older leaves	None
111–108	10	Some burning of older leaves; new shoots healthy	No control

*Results based on treatment of one to six plants.

SUBMERSION OF LEAVES IN HOT WATER

The submersion of potted plants in hot water lethal to the nematode should provide a source of clean leaves for further propagation of the stock. However, it would seem even better to use the hot-water treatment on selected healthy begonia leaves from infested stock before rooting them in sand if they could tolerate the treatment. Leaves were gathered in November and given various hot-water treatments to determine the safety of this practice. Twenty-nine temperature treatments of infested and non-infested leaves from Lady Mac and Marjorie Gibbs begonias were compared. Rooting was appreciably reduced by the higher temperature baths when infested leaves were employed. The infested leaf blades were badly injured by the high temperatures and most of the stock was lost after shifting from the sand. When healthy leaves were employed, rooting was not affected by those temperatures previously shown to be lethal to the nematode and the leaf blades were not injured. (Table 2). The hot-water treatment of leaf-cuttings is thus an efficient means of freeing the leaves of any possible but inapparant infestation of the leaf-blight nematode and gives assurance of starting the new propagation clean. This treatment should serve as a desirable sanitary practice in preventing the introduction of the organism into the clean sand bench, but it is advocated only when the disease exists in the stock.

Table 2.—Effect of Hot-Water Treatment of Begonia Leaves on Rooting*

Temperature °F.	Time (Minutes)	Percentage Rooting	
		Infested Leaves	Healthy Leaves
124	1	0	
123–122	1		100
122	1	25	
122–121½	1		100
121–120	1		92.8
120–119	1	0	
119	1	33.3	
118	1	25	
121–120	2		100
120–119½	2		85.7
119–118¼	2		100
120–119	3	0	
119–118	3		92.8
118–117	3	75	
118–116¼	3		100
117–115½	3		100
116	3	91.6	
114–113	3	91.6	
116–115	5	58.3	
116–113½	5		100
115–113	5		100
114–113	5	83.3	
112	5	66.6	
114–113	7	91.6	
112	7	100	
110	7	58.3	
112–111	10	66.6	
110	10	66.6	
No Treatment			100

*Results based on treatment of 12 leaves.

PRACTICAL CONSIDERATIONS AND RECOMMENDATIONS

The treatment of potted begonias with hot water to be practical must be a rapid operation, especially if a large amount of stock is involved. Submersion of stock in hot water for not more than three minutes, with a short interval after the treatment of each lot of plants to permit the restoration of the maximum temperature of the bath water for the next lot, will enable the grower to do the work in the shortest time.

The treatment must be safe. Soaking of the soil in the pots would result from a long period of submersion and this would promote decay and damage to the root system. A five-minute treatment, therefore, would be objectionable and is not necessary from the standpoint of control.

A tank large enough to accommodate a rack of 25 plants seems necessary where a large amount of stock is involved. The volume of water must be sufficient to prevent a temperature drop of more than 3° F. during the period of submersion. As the plants are lifted from the water, they should be tipped to one side to release any water on the soil in the pots.

As insurance against serious trouble later, the hot-water treatment of begonia stock would seem to be advisable on the first appearance of symptoms of the leaf-blight nematode disease. Submersion of the plants would be more practical in 3½-inch pots than in 5- or 5½-inch pots and there would be more time for the renewal of shoots and leaves. Treatment after the first of October is not desirable since the subsequent growing period, extending to the Christmas marketing season, is too short to make possible a luxuriant amount of new growth.

All diseased leaves should be removed and destroyed before the hot-water bath. Diseased leaves which escape removal are injured by the treatment even though but slightly infested.

Accurate thermometers in one- or two-degree graduations, accuracy in operation, and agitation of the bath water during the treatment are important.

Although there is no particular evidence to show the value of shading in this work with begonias, it is, according to Smith (11), desirable to give this protection to certain florists' crops for 24 to 48 hours after a 15-minute treatment at 110° F. as a precaution against injury. Staniland and Beaumont (12, 13), working with strawberry and violet runners, advise, instead, plunging the stock in cold water immediately after the hot-water bath.

In view of the foregoing considerations, treatment for one minute at 121-120° F., two minutes at 119-117° F., or three minutes at 118-115° F. is recommended when the disease exists in the stock. The highest water temperature should prevail at the beginning of the submersion period and the maximum temperature should be restored for each new lot of plants. In view of the varying conditions under which the plants are grown in different establishments and the fact that such conditions can influence susceptibility to injury, it is strongly recommended that the grower first treat a small number of potted plants of each susceptible variety before undertaking treatment of the entire lot.

The same temperature-interval water baths are recommended for healthy leaves selected for propagating from stock where the disease exists. The leaves should be placed in a closed wire basket or carefully wrapped in cheesecloth and completely submerged during the interval of treatment.

SUMMARY

The culture of Lady Mac, Melior, and Marjorie Gibbs begonias represents a large enterprise in many floricultural establishments in Massachusetts. The leaf-infesting nematode, *Aphelenchoides fragariae* (Ritzema-Bos 1891) Christie 1932, commonly known as *Aphelenchus olesistus* Ritzema-Bos, is often a serious menace to the successful culture of these begonias.

Sanitary and cultural methods within the limits of good plant growth and commercial practice are not effective in arresting the progress of the disease. Propagating from stock free of the leaf-blight nematode disease is the best measure of control, other desirable sanitary and cultural practices being followed.

All stages of the nematode in the leaves are killed by submerging potted infested plants in water of a mean temperature of 115° F. for 5 minutes, 117° F. for 3 minutes, 118½° F. for 2 minutes and 120½° F. for 1 minute. In general, temperatures of 123°-120° F. for 1 minute, 118°-115° for 3 minutes and 115°-113° F. for 5 minutes were safe except to infested leaves, which were severely injured. In a few instances a trace or a very small number of nematodes revived after the treatments but either no further symptoms of disease appeared or the amount of disease after 3 months was negligible. Untreated stock continued to show infested leaves and ultimately the contrast between treated and untreated plants was striking.

Submersion of plants in water at temperatures of 121°-120° F. for 1 minute, 119°-117° F. for 2 minutes, or 118°-115° F. for 3 minutes is recommended for infested stock. The treatments should be tried on a few plants before they are applied on a large scale.

The submersion of begonia plants in hot water as an eradicative control measure should be done at least three months before the marketing season to permit the development of well-foliaged plants during the ensuing interval. The treatment of small plants earlier in the season, when an infestation first becomes noticeable, would be even more practical.

Leaves selected for propagating tolerate water baths of these temperature-intervals, and the treatment of healthy leaf-cuttings from infested or unfamiliar outside sources during the winter propagating season is recommended as a means to a clean start.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 349 February, 1938

Shade Tree Law in Massachusetts

By Edward T. Simoneau

The value of shade trees is recognized in Massachusetts, as is evidenced by the numerous laws enacted relative to their care. This bulletin is intended to set forth the operation of these statutes as they affect this important natural resource.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

The subject matter of this treatise on shade tree law was first presented by Judge Edward T. Simoneau in the capacity of visiting lecturer at the course for tree wardens and town foresters, March 22-27, 1937. The course is offered annually at Massachusetts State College through the cooperation of the Departments of Botany, Entomology, Forestry, and Landscape Architecture, together with visiting lecturers.

The meritorious character of Judge Simoneau's contribution as a rather searching treatment of his subject and a valuable service to the people of Massachusetts promptly attracted much-deserved recognition. In view of the foregoing and also because of numerous requests for copies of the discourse received from persons in attendance at the 1937 tree warden's course and from the general public, this discussion of modern laws on a subject incipient in the codes of Ancient Greece and Rome is published by the Experiment Station.

F. J. SIEVERS, *Director*.

SHADE TREE LAW IN MASSACHUSETTS

By Edward T. Simoneau, LL.B.[1]

The law relative to the care, preservation and maintenance of public shade trees in this commonwealth is wholly statutory, and one chapter of the General Laws, chapter 87, is devoted exclusively to that subject. Other provisions of law relating to public shade trees, which I shall discuss later in this paper, are to be found in other parts of the General Laws.

> The planting, maintenance, care and removal of shade trees in highways is a service purely public in its nature, undertaken for the common good and without any element of private gain or special advantage to the municipality. Shade trees, though not originally the subject of legislative action, have been regulated to a very considerable and increasing extent by statute in recent years, until now the whole range of municipal action respecting them is covered. There is little if anything left to local control. The definition of public shade trees is statutory, and the discretion and sound judgment of an officer appointed by local authority controls wholly their care, preservation and removal. Shade trees are not objects of utility, but rather of beauty, grace and refreshment. The motive which prompts their planting and the object to be attained by their cultivation is a general benefit. Although the expediency and extent of municipal activity is left to the wisdom of local instrumentalities of government and is not imperatively determined by the Legislature, the character of such beneficial work is distinctly the public weal rather than any private emolument of the city or town. It is plain that under principles firmly established in our law, the performance of these functions constitutes not private acts, but public service.[2]

With this statement by the learned Chief Justice of the Supreme Judicial Court, we may proceed with a discussion of the legislative history of the laws relating to public shade trees and those now in force in this jurisdiction.

EARLY SHADE TREE LAWS

The evolution of the shade tree law in Massachusetts was of considerable duration. The first general law in this commonwealth in which we find any mention of trees on public ways was passed in 1786,[3] in which it was provided that highway surveyors "shall have full power . . . to cut down or lop off all trees and bushes, . . . that shall in any manner obstruct or incumber any highway or town way, or hinder, incommode or endanger persons travelling thereon; . . ." This law was amended in 1796,[4] and was re-enacted in the several revisions of the general laws down to 1880.[5]

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[1] Of Marlborough, Massachusetts. Special Justice of the District Court of Marlborough, Professor of Municipal Government, Suffolk University, and former Assistant Attorney General of Massachusetts.

[2] Chief Justice Rugg in Donohue v. Newburyport, 211 Mass. 561, at page 564.

[3] St. 1786, c. 81, § 1.

[4] St. 1796, c. 58, § 12.

[5] St. 1885, c. 123, § 2.

The first legislation on the subject of shade trees was passed in 1856.[6] It was therein provided that the mayor and aldermen of cities and the selectmen of towns, or any municipal officer to whom the care of streets or roads was intrusted might "authorize the planting of shade trees", wherever they would "not interfere with the public travel, or with private rights"; and that "such trees planted pursuant to such license" were to be deemed and taken to be the private property of the persons planting them, and to be protected "in the same manner as any other private property." It was declared in that statute that trees planted under a license were not to be "deemed a nuisance, or abated as such, except upon complaint made to the mayor and aldermen or selectmen . . . ", who "in case of complaint" could "cause such trees to be removed, if the public necessity" seemed "to them to require their removal." It was made a criminal offence wantonly to "injure, deface, tear or destroy any ornamental or shade tree or shrub" in any street, road, square, court, park, public garden or other enclosure. For each offence a penalty of not less than five, nor more than one hundred dollars was provided, which was to be recovered by complaint in any court of competent jurisdiction; one half of which penalty was to be paid to the complainant and the other half to the person upon whose property the trespass was committed.

In the following year, municipalities through the mayor and aldermen or selectmen were enabled to "set out and maintain shade trees, upon public squares and highways, at the expense of the city or town"; and authority was granted to appropriate annually for such purposes, "a sum not exceeding twenty-five cents for each of its ratable polls in the year next preceding"; provided, the law was accepted by the city council of a city, "or the inhabitants of a town, at a legal meeting."[7]

By an act passed in 1859, a person who negligently or carelessly suffered any horse or other beast driven by him, or any beast owned by him and lawfully on the highway or other public way, to break down, destroy or injure any tree not his own, standing for use or ornament on the highway, or who negligently or wilfully, by any other means, broke down, destroyed or injured any such tree, was subject to an action for damages, at the suit of the owner or tenant of the land in front of which the tree stood.[8] These statutes were made a part of Chapter 46 of the General Statutes (Revision of 1860). It is to be noted that no particular officer was given charge of public shade trees, and that the term "shade tree" was defined.

The first law which imposed any obligation, except upon the surveyor of highways as stated previously, with respect to shade trees, was passed in 1867.[9] It was permissive, and was effective only on acceptance by a town at a town meeting, or a city by the city council. In any municipality which accepted this law, a person who had by law a right to cut down or remove any ornamental or shade tree standing in any highway, town way or street could not exercise that right without first giving notice of his intention so to do to one of the selectmen of the town or the mayor of a city. If these officers desired to retain the tree, they were required to give notice to such person within ten days after his notice to them, and in that case the laws relative to assessment, appeal, final determination and payment of the damage such person suffered by the retaining of the trees as in the case of damage done by an alteration of such way were applicable. Provision was made for the imposition of a forfeiture of not less than five nor more than one hundred dollars upon a person who cut down, removed or injured such tree without first giving notice to the selectmen or mayor. The penalty accrued to the town or city.

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[6] St. 1856, c. 256.
[7] St. 1857, c. 115.
[8] St. 1859, c. 261.
[9] St. 1867, c. 242.

In 1880, the power given to the surveyor of highways to "cut down or lop off all trees and bushes" by the act of 1786, was curtailed somewhat. An act approved on March 5, 1880, prohibited him from cutting down or lopping off such trees as were needed for shade trees.[10] These several statutes were reenacted into the Public Statutes of Massachusetts.

In 1885, the amount which might be appropriated for the planting of shade trees was increased to a "sum not exceeding fifty cents for each of its ratable polls in the preceding year, to be expended in planting, or encouraging the planting by the owners of adjoining real estate, of shade trees upon the public squares or highways, and may plant such trees . . . "[11] In the same act[12] the powers of the surveyor of highways were further curtailed. It was provided that the "officer appointed to have the care of trees belonging to a city or town and his assistants, but no other person except as is provided in the following section (P. S. c. 52, § 11) and in section ten of chapter fifty-four, may, and when required by the surveyors of highways or road commissioners shall trim or lop off trees and bushes standing in highways, town ways, streets or lanes, and, when ordered by a vote of the mayor and aldermen, selectmen or road commissioners passed after public notice and hearing shall cut down and remove such trees;".

By act passed in 1890,[13] the mayor and aldermen of cities and selectmen of towns were authorized to designate and preserve trees within the limits of the highways for purposes of ornament and shade, and to designate not less than one such tree in every thirty-three feet where they were growing and were of diameter of one inch or more. In each year between the first day of September and the thirty-first day of December, these officials were also required to designate the trees selected by them by driving into the same, at a point not less than six feet from the ground and on the side of the tree facing the highway, a spike or nail, with the letter "M" impressed upon it. These spikes or nails were furnished by the secretary of state. They were also required, during the same months in the succeeding year, to renew such of the spikes or nails as had been destroyed or defaced; and also to designate such other trees as in their judgment should be so designated.

A penalty of not less than five nor more than one hundred dollars was provided for wanton injury, defacement or destruction of any tree thus designated or any of the nails or spikes. An inconsequential change was made in 1891,[14] viz: spikes or nails were to be furnished by the state board of agriculture rather than by the secretary of state. The time during which the trees were to be designated and the spikes and nails renewed was changed from October, November and

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[10] St. 1880, c. 62.

[11] St. 1885, c. 123, § 1.

[12] St. 1885, c. 123, § 2.

[13] St. 1890, c. 196.

[14] St. 1891, c. 49.

December to "such seasons of the year as they deem proper" by an act passed in 1892.[15]

By a statute of 1893, the affixing of a playbill, poster notice, advertisement or printed matter on, or the cutting, painting or marking of trees, except for the purpose of protecting such trees, without first obtaining a permit from the officer having charge of such trees in a city or from the selectmen, was made a criminal offence, punishable by a fine of not less than five nor more than fifty dollars.

In 1893, the care of shade trees was given to road commissioners in towns choosing such officers; and the superintendent of streets in towns where this official was appointed, was given "the care and preservation of shade trees," under the direction of the selectmen.[16]

The General Court in 1896 authorized towns to elect tree wardens at the annual elections, to serve for one year. This officer was given "full care and control of all public trees in the town", and had "charge of the expenditure of all public funds appropriated or granted for setting out shade trees", and he could "order the removal of . . . shade trees or parts thereof", as he "might determine to be for the best interests of the public, after hearing parties interested." He was prohibited from cutting down, removing or injuring any live public shade tree, until he had given public notice of his intention so to do by posting a notice on the tree and in at least seven places in the town. He was required to appoint a suitable time and place for hearing all parties interested, to attend at the time and place appointed, hear all parties interested, and determine the necessity or expediency of such removal. His decision was final. He was empowered to enter and prosecute complaints for malicious injury to, or unlawful acts concerning public shade trees.[17]

Permissive legislation was enacted in 1897 providing for the appointment of foresters. If this statute was accepted in a town, the forester was given charge of "all trees within the limits of a highway, public way or square . . . " and had and exercised all the powers and was subject "to all the restrictions granted to and imposed upon tree wardens." The duty of enforcing "all the provisions of law relating to the setting out, cultivation and preservation of shade, ornamental . . . trees" was imposed upon him.[18]

It requires no extended discussion to point out the confusion which must have resulted from the multitudinous and apparently inconsistent legislation passed up to this time (1897) and then in force. In Wright v. Chelsea, 207 Mass. 460, the court, in reviewing the enactments on the subject of shade trees from 1885 to 1897, said at page 463: "It would not have been strange if voters and officers in towns may have been somewhat perplexed as to the effect of these several enactments."

In 1899, the Legislature codified and amended the laws relative to the preservation of public shade trees. This law applied to towns exclusively. Under this codification the election of a tree warden was mandatory. The term of office was "one year and until his successor was elected and qualified." Upon the tree warden devolved the care and control of all public shade trees in the town, except those in public parks or open spaces under the jurisdiction of park commissioners, and of those if requested in writing by the park commissioners; the expenditure of all funds appropriated for the setting out and maintenance of such trees; and the duty to enforce all provisions of law for the preservation of such trees. He was authorized to prescribe such regulations for the care and preservation of such trees, enforced by suitable fines and forfeitures, as he deemed just and expedient, but not exceeding twenty dollars in any one case; and such regulations when approved by the selectmen and posted in two or more public places in the town, had the force and effect of town by-laws.

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[15] St. 1892, c. 147.

[16] St. 1893, c. 423.

[17] St. 1896, c. 190.

[18] St. 1897, c. 254.

All shade trees within the limits of any public way were declared to be public shade trees. Towns were permitted to appropriate "annually a sum of money not exceeding in the aggregate fifty cents for each of its ratable polls in the preceding year to be expended by the tree warden in planting shade trees in public ways", and "upon adjoining land, if he deemed it expedient, at a distance not exceeding twenty feet from said public ways, for the purpose of shading or ornamenting the same"; provided, he first obtained the written consent of the owner of such land.

All persons, except the tree warden, were prohibited from cutting or removing, in whole or in part any public shade tree, and if any person desired the cutting or removal of a public shade tree, he had to apply to the tree warden, who upon an application to him was required to give a public hearing at some suitable time and place, after duly posting notices of the hearing in two or more public places in the town and also upon the tree. If he deemed it expedient, he could grant permission for such cutting or removal, without calling a public hearing, if the tree in question was on a public way outside of a residential part of the town, the limits of such residential part to be determined by the selectmen; but no tree within a residential part of a town was to be cut by him without a hearing, and in all cases his decision was final.

Towns were authorized to appropriate and raise money to be expended by the tree warden for the extermination of insect pests within the limits of the public ways and places and in the removal of all trees and other plants "upon which such pests naturally breed."

In this codification, the previous penal statutes relative to affixing playbills, etc., the wanton injury to or the negligent or careless suffering of horses or other beasts to break down, injure or destroy shade trees were re-enacted. The duty of enforcing the laws on shade trees was imposed upon the tree warden.

The provisions of the codification of 1899 as well as other laws pertaining to shade trees were re-enacted in the Revised Laws of 1902.

The first law relative to shade trees within the limits of state highways was passed in 1905,[19] and the care and control of such trees were vested in the Massachusetts Highway Commission.

In 1908, the Legislature repealed so much of the Revised Laws, c. 53, § 6, as granted authority to the selectmen or road commissioners of towns to authorize the planting of shade trees in public ways.[20] This authority was transferred to the tree warden by the following provision: "No tree shall be planted within the limits of a public way without the approval of the tree warden, and until a location therefor has been obtained from the selectmen or road commissioners where the authority has been vested in them."[21] The discretion given to the tree warden by the 1899 statute to permit the cutting or removal of trees outside the residential part of the town was taken away from him."[22]

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[19] St. 1905, c. 279.

[20] St. 1908, c. 296, §1.

By St. 1910, c. 363, § 1, the powers and duties of tree wardens in towns under R. L. c. 53, § 12, and as amended by St. 1908, c. 96, were conferred and imposed upon officials charged with the care of shade trees within the highways in cities, by the charters of cities, or by other legislative enactment or by ordinances.

By section 2 of this act, Revised Laws, c. 53, § 6, (providing for the planting and removal of shade trees), § 7, (providing for the removal of shade trees in cities), § 8, (providing penalties for unlawful removal of shade trees), §9, (relative to preservation of shade trees in cities), § 10, (with respect to the manner of designating shade trees), and § 11, (imposing penalties for injuries to trees) were repealed.

In 1915, the Legislature by General Acts, c. 145, codified and amended the laws relative to shade trees. There were no changes made between that date and the re-arrangement and consolidation of the General Laws in 1920. The provisions of Act of 1915 were re-enacted in chapter 87 of the General Laws, and a full discussion of the statute now in force follows.

THE PRESENT SHADE TREE STATUTES

"All trees within a public way or on the boundaries thereof are public shade trees." No distinction is made as to the species. They may be of the kinds ordinarily used for shade or ornamentation, or they may be fruit trees. If, in any proceeding in which it appears that the ownership of or rights in a tree are material, and that, from length of time or otherwise, the boundaries of the highway cannot be made certain by records or monuments, and for that reason it is doubtful whether the tree is within the highway, it shall be taken to be within the highway until the contrary is shown.[23]

Towns are authorized to appropriate money to be expended in planting shade trees in public ways, and for their care and maintenance.[24]

If a city council of a city, or a town at a town meeting accepts the provisions of General Laws (Ter. Ed.) c. 82, § 4, or the corresponding provisions of earlier laws, the board of officers authorized to lay out highways or town ways may reserve spaces between the side lines thereof for "trees and grass and planting."

Ten or more persons in any county, city or town may form a corporation for the purpose of improving and ornamenting the streets, and squares of any city or town, by planting and cultivating trees therein.[25]

In towns, the care and control of public shade trees are vested in an official called the tree warden.[26] Every town at its annual town meeting chooses by ballot a tree warden for the term of one year.[27] He may be appointed by the selectmen if the town votes affirmatively by the official ballot upon a petition by ten per cent of the registered voters filed with the selectmen thirty days or more before an annual town meeting asking that he be so appointed.[28]

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[21] St. 1908, c. 296, § 2.

[22] St. 1908, c. 296, § 1.

[23] G. L. (Ter. Ed.), c. 87, § 1.

[24] G. L. (Ter. Ed.), c. 40, § 5, cl. 10.

[25] G. L. (Ter. Ed.), c. 180, § 3.

[26] G. L. (Ter. Ed.), c. 87, § 2.

[27] G. L. (Ter. Ed.), c. 41, § 1.

A town may, after a vote authorizing the selectmen to appoint a tree warden has been in effect for a period of not less than three years, by a vote at a meeting held at least thirty days before the annual town meeting, rescind such action, and thereupon the town shall at the next town meeting nominate and elect a tree warden.[29]

There is no general law requiring the election or appointment of tree wardens in cities. By section 13 of chapter 87, of the General Laws (Ter. Ed.), the powers and duties conferred and imposed upon tree wardens in towns by that chapter "shall be exercised and performed in cities by the officers charged with the care of shade trees within the limits of the highways." These officers may be "charged with the care of shade trees" by city charters or ordinances of the city.

The tree warden derives all of his powers from the Legislature, and is a public officer. His "functions constitute not private acts, but public service."[30] A public officer "is one whose duties are in their nature public, that is, involving in their performance the exercise of some portion of the sovereign power, whether great or small, and in whose proper performance all citizens, . . . are interested, either as members of the entire body politic, or of some duly established division of it."[31]

The care, control and maintenance of public shade trees is an act of sovereignty.[32] In Whiting v. Board of Public Works of Holyoke, 222 Mass. 22, 26 (1915) the court speaking through Mr. Justice Braley said:

> The legislation concerning public shade trees has been enacted from time to time not merely to satisfy the desire of cities and towns for the conservation in their thoroughfares of shade and ornamental trees, in many instances a legacy from the past or the gift of public spirited citizens, but for the benefit and enjoyment of all the inhabitants of the Commonwealth having occasion to use the public ways.

The powers and duties of the tree warden may not be abridged or enlarged or controlled by any act or vote of the town. Only the Legislature may do this.

The town is not liable for any negligent act of the tree warden. "This principle of exoneration is not one of narrow or technical reasoning, but rests upon the broad foundation widely accepted in most jurisdictions, that an agency of government, while engaged upon duties imposed solely for the benefit of the public, is not liable for the negligent performance of such duty."[33] Although appointed and paid for by the town, the person performing the duties imposed under a legislative mandate is not a private agent or servant, but a public officer.[34]

The tree warden is not relieved of personal liability if he commits a tort whether by negligence or otherwise in the performance of his duties.

The tree warden has the care and control of all public shade trees, shrubs and growth in the town, except those within a state highway, and those in public parks or open places under the jurisdiction of the park commissioners. He may have control of the latter, if so requested in writing by the park commissioners.[35]

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[28] G. L. (Ter. Ed.), c. 41, § 21.

[29] G. L. (Ter. Ed.), c. 41, § 23.

[30] Donohue v. Newburyport, 211 Mass. 561.

[31] Attorney General v. Drohan, 169 Mass. 534, 535.

[32] Donohue v. Newburyport, 211 Mass. 561. McCarthy v. Boston, 135 Mass. 197.

[33] Donohue v. Newburyport, 211 Mass. 561.

[34] Donohue v. Newburyport, 211 Mass. 561.

I construe the word "care" as used in this statute to mean "maintenance" and "preservation", and, consequently, the tree warden is authorized to do everything which can be reasonably done to preserve and maintain public shade trees.

The word "control" as used in this connection was considered in Sharon v. Smith, 180 Mass. 539, (1902) in which the court said:

> In view of the prior legislation on this matter, . . . , we think that the care and control given to the tree warden is in substance the same as that which had been theretofore exercised by various town officers, and that the ruling that the prohibition in the statute refers to an interference not authorized by law with shade trees and that the statute is not to be so construed as to give to the tree warden supreme power over a tree as against the power of the town to locate guide boards, is correct.

The tree warden expends all money appropriated for the setting out and maintenance of such trees, shrubs and growths, and no tree shall be planted within a public way without his approval, "and in towns until a location therefor has been obtained from the selectmen or road commissioners."[36] He may, if he deems it expedient, plant shade trees upon land adjoining public ways, at a distance not exceeding twenty feet from such ways, for the purpose of improving, protecting, shading or ornamenting the same; provided, that written consent of the adjoining land owner shall be first obtained.[37] The granting of a location in a public way for the planting of shade trees is not an alternative function of the selectmen or road commissioners. The tree warden should determine what board has jurisdiction. If a surveyor of highways is chosen in the town, application should be made to the selectmen; but if the town has voted to elect road commissioners, the application for the granting of a location should be made to this latter board, for it is provided in G. L. (Ter. Ed.) c. 41, § 64:

> If road commissioners be chosen, they shall exclusively have the powers, perform the duties and be subject to the liabilities and penalties of selectmen and surveyors of highways relative to public ways, monuments at the termini and angles thereof, guide posts, sidewalks and shade trees, and, if sewer commissioners be not chosen, relative to sewers and drains.

The tree warden may make regulations for the care and preservation of public shade trees, and establish fines and forfeitures of not more than twenty dollars in any one case for violation thereof. Such regulations as may be promulgated by him must be posted in one or more public places, and in towns, approved by the selectmen before they become effective. When so posted and approved, they have the effect of town by-laws.[38]

The tree warden of a town may appoint and remove deputy tree wardens. He and they shall receive such compensation as the town determines, or in default thereof, as the selectmen allow.[39] He may hold the office of forest warden.[40] In a town where there is no officer charged with the suppression of gypsy and brown tail moths "the tree warden may destroy within the limits of his city or town the tent caterpillar, leopard moth and elm tree beetle or any other tree- or shrub-destroying pest, if authorized so to do by the mayor and city council or by the selectmen.[41]

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[35] G. L. (Ter. Ed.), c. 87, § 2.

[36] G. L. (Ter. Ed.), c. 87, § 2.

[37] G. L. (Ter. Ed.), c. 87, § 7.

[38] G. L. (Ter. Ed.), c. 87, § 2.

[39] G. L. (Ter. Ed.), c. 87, § 2.

[40] G. L. (Ter. Ed.), c. 48, § 8.

The statute prohibits the cutting down, trimming or removal of any public shade tree less than one and one-half inches in diameter one foot from the ground in whole or in part by any person, even if he be the owner of the fee on which such tree is situated, other than the tree warden or his deputy, except upon a permit in writing from the tree warden. No tree warden or his deputy or other person shall cut down or remove a public shade tree without a public hearing at a suitable time and place, after a notice thereof posted in two or more public places in the town and upon the tree at least seven days before such hearing, and after authority is granted by the tree warden.[42]

It is suggested that the tree warden strictly observe the requirements of these provisions, otherwise, any action authorized by him will be a nullity. If he commits an error of law, his acts may be reviewed by certiorari.

If a person is injured in his property by the action of the officers in charge of the public shade trees as to the trimming, cutting, removal or retention of any such trees, or as to the amount awarded to him for the same, he may recover the damages, if any, which he has sustained, from the town under the provisions of law relating to eminent domain (land takings). G. L. (Ter. Ed.) c. 79.[43]

In such cases, damages, if any, shall be awarded by the tree warden. The damages shall be assessed as of the day the act is done.[44] In the event that no damages are awarded or that the award, if one is made, is insufficient, the person claiming to be injured must bring a petition for the assessment of damages in the Superior Court for the county in which the town is situated within one year of the date of the alleged injury.

The provisions of G. L. (Ter. Ed.) c. 87, § 3, relative to injury by trimming, cutting, removal, or retention of a public shade tree do not authorize the bringing of a petition for damages sustained by reason of injury to property for the falling down of a decayed tree.

Cody v. North Adams, 265 Mass. 65, was a petition for damages to the plaintiff's house by the falling of a tree because of its decayed condition. The court, speaking through Mr. Justice Carroll, said:

> Under the statute, G. L. c. 87, § 3, the tree could not be removed by the commissioner of public works until after a public hearing at which the parties interested might have an opportunity to be heard. As there was no such hearing, the remedy given to the party injured in her property does not apply. That remedy is purely statutory; it is not given for mere neglect to remove a tree standing in the public highway and which falls upon the house of any adjoining owner, when there has been no public hearing. The failure of the commissioner to remove the tree did not give the petitioner a right to damages under the eminent domain statute.[45]

The petitioner in the same case contended that the retention of the tree by the city gave a right to damages to one injured in his property by the mere fact that such officers permitted a shade tree causing damage to remain in the highway. In answering this contention, the court said:

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[41] G. L. (Ter. Ed.), c. 132, § 25.

[42] G. L. (Ter. Ed.), c. 87, § 3.

[43] G. L. (Ter. Ed.), c. 87, § 3.

[44] G. L. (Ter. Ed.), c. 79, § 10

[45] Under the provisions of the city charter of the city of North Adams, the commissioner of public works had the powers and duties of a tree warden.

> The petitioner contends that the natural meaning of the word "retention" as used in the statute is to give a right to damages to one injured in property by the mere fact that such officers permit a shade tree causing damage to remain in the highway. The word "retaining" appears in St. 1867, c. 242, § 1. That section recognized the private ownership of all shade trees to be in the abutting owner, but forbade him to cut down such trees without first giving notice to public officers who might "retain" such tree as a shade tree; and in that event the owner could recover damages according to the highway law. The retention of the tree in those circumstances was an act of eminent domain. In subsequent statutes the word "retention" is used, and the continuation of the word, particularly in St. 1915, c. 145, §§3, 8, and G. L. c. 87, §§ 3, 8, indicates that it is to continue to have the same meaning as "retaining" when that word originally appeared in our statutes, and as in the case at bar the requirements of the section (§ 3) were not complied with the petitioner cannot recover.

A somewhat similar case was presented in the case of Jones v. Great Barrington, 269 Mass. 202. In this case the facts found by the auditor to whom it was referred disclosed that the petitioner was the owner of real estate with a dwelling house thereon, situated on the northerly side of Main Street, a public way, in the village of Housatonic in the defendant town. For a long time there had existed on or near the boundaries of the plaintiff's premises and within, or near the boundaries of said premises, or near the boundaries of the highway, a public shade tree approximately nine feet in circumference at its base, over fifty feet in height, and from fifty to sixty years old. In 1916, the petitioner was informed that the tree was in a dangerous condition; there was a hole or cavity in its trunk, about twenty feet from the ground, which could easily be seen. He brought the attention of the then tree warden to the condition of the tree, and the warden agreed to look after it, but he never did. In 1923, the plaintiff spoke to a member of the board of selectmen in regard to the tree, and was told that the tree was in pretty good condition and that he had no right to cut or remove it. In the spring of 1925, the plaintiff spoke to the then tree warden about the condition of the tree who told him he would look into the matter, but he never did. In 1926, the petitioner stated to the road superintendent of the town that the tree was dangerous and asked him to see about taking it down. The road superintendent promised to report it to the board of selectmen and see what they would do about it. Other than the tree wardens, none of the town officials referred to ever had anything to do with the care of trees, except to investigate when trees were reported in bad condition and bring it to the attention of the tree warden. No public hearing in respect to the cutting, trimming or retention of the shade tree was ever called or held in accordance with the provisions of G. L. c. 87, § 3.

On the evening of October 12, 1927, during a severe but not unusual storm of wind and rain, the tree, on account of its decayed condition, was blown over upon the dwelling of the petitioner causing damages to the house. Prior to the blowing over of the shade tree, no one in the employ of the town ever pruned, trimmed, sprayed or did anything about the tree except to speak to the above named officials about its condition. In the Superior Court judgment was rendered for the town.

The petitioner contended in his argument to the Supreme Judicial Court that the shade tree was dangerous to travellers; that the non-action of the officers in charge of highways whereby the tree was permitted to stand after their attention had been brought to its condition in 1916, and their failure to convoke a public hearing under G. L. c. 87, § 3, or to permit him to cut the tree down or to order the same to be cut down by the tree warden as endangering travel on the public way for a period of eleven years, constituted a retention of the tree within the meaning of G. L. c. 87, § 3, and attempted to distinguish this case from Cody v. North Adams, 265 Mass. 65, which I discussed previously.

The court held that this case was governed by Cody v. North Adams, sustained the decision of the judge of the Superior Court, and in the course of its opinion said:

> No statute of this commonwealth in terms makes any provision for a petition under the eminent domain act, G. L. c. 79, to recover damages to person or property sustained by reason of the failure of public officials to remove or make safe trees which endanger, hinder or incommode travel on a public way.

After this decision was handed down, a new action was brought by the petitioner, and he was permitted to recover on another ground, which I shall treat later.

I have not been able to find any decision of the Supreme Judicial Court in which the precise question of the right to recover damages to property resulting from the "trimming, cutting, removal or retention of any such tree" has been presented for determination. In order that this point may be understood, let us discuss two supposititious cases:

1. Let us assume the facts as to the condition of the shade trees before they were blown down in either of the cases of Cody v. North Adams, 265 Mass. 65, and Jones v. Great Barrington, 269 Mass. 202, as the basis of our first hypothetical case. If Cody had applied to the tree warden to cut down the tree, and, after a full compliance with G. L. c. 87, § 3, that is, the giving of notice and the holding of a public hearing, the tree warden decided to retain the tree, Cody could recover for the damage to his property, that is, the lessening of the value of his property because of the retention of the tree. The value of his property would be decreased because of the danger of the injury which might be inflicted on persons who might occupy the house, and of damage to the building and its contents. Of course, no one would pay the real value of the property under such circumstances. Who would want to occupy the premises when danger was so iminent!

2. In our second hypothetical case, let us assume the following facts: A is the owner of a piece of real estate ideally situated for residential purposes, and large shade trees are standing in the highway and in front of his premises, which add to the appearance of his premises, and also to his comfort and enjoyment. For some reason, the tree warden believes that these trees should be removed, and convokes a public hearing, and grants authority to remove them and the cutting or removal is approved by the selectmen or the mayor. (Remember this is a supposititious case, and I hardly think any sane tree warden, mayor or selectmen would do anything like this.) A right of action would accrue to A, and he could maintain a petition for the assessment of damages under the eminent domain laws, G. L. (Ter. Ed.) c. 79, for the damages resulting to him because of the diminution in the value of his property.

The Legislature, however, has imposed limitations upon the tree warden with respect to the cutting down or removal of a public shade tree. If, at or before a public hearing as required, objection to the cutting or removal is made in writing by one or more persons, he may not cut or remove such tree "unless such cutting or removal or permit to cut or remove is approved by the selectmen or by the mayor."[46]

The word "approval" has been defined by the Supreme Judicial Court as follows:

> Approval implies favorable conviction manifested by affirmation concerning a specific matter submitted for decision. It does not import initiative. Approval ordinarily indicates the will to assent to an act done by someone else rather than the doing of that act . . . It signifies the application of sound judgment to a proposition emanating from another source and submitted for investigation. It requires the exercise of faculties of criticism and discrimination. It denotes positive sanction. It does not mean original and inventive construction in the first instance. On the other hand, it is not a mere perfunctory act. It imposes no mean responsibility. It carries power and duty of an effective nature.[47]

In Graham v. Board of Public Works of Pittsfield, 285 Mass. 544, it was held that the action of the board of public works of Pittsfield, who under the city charter performed the duties of tree warden, in ordering the removal of shade trees in a public way was of no effect, because, objections having been made to their removal, it had not been approved by the mayor. The removal of the trees was enjoined by the court.

There are exceptions, however. If the mayor of a city, selectmen of a town, road commissioners or highway surveyor deem that a public shade tree obstructs, endangers, hinders or incommodes persons travelling on a public way within the city or town, they or any of them may order the tree warden to trim or cut down such tree or bushes. In case such order is given, no public hearing is required, and it is the duty of the warden to carry it out.

I think that the rule which I have previously stated with respect to the granting of location for the planting of trees by the selectmen ought to be modified somewhat in its application to the ordering of the trimming or cutting down of trees. Selectmen are the executive and administrative officers of the town. "Speaking generally, it may be said that they are agents to take the general superintendence of the business of a town; to supervise the doings of subordinate agents, and the disbursement of moneys, appropriated by vote of the town, to take care of its property and perform other similar duties . . . They can exercise such powers and perform such duties as are necessarily and properly incident to the special and limited authority conferred on them by their office. They are special agents, empowered to do only such acts as are required to meet the exigencies of ordinary town business."[48] If it should be brought to their attention that a public shade tree obstructs, endangers, hinders or incommodes persons travelling on ways, it would be their duty to order the trimming or cutting of such trees.

If the officers authorized to lay out highways shall order the trimming, cutting or removal of any public shade tree "for the purpose of widening the highway", no notice or public hearing is required, and it is the duty of the tree warden to carry out such order.[49]

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[46] G. L. (Ter. Ed.), c. 87, § 4.

[47] Simpson v. Marlborough, 236 Mass. 214.

[48] Smith v. Cheshire, 13 Gray, 318, 319.

A strict interpretation of the provisions of the statute to which I have just referred would limit the authority to order the tree warden to trim, cut or remove a public shade tree to the county commissioners, but I think the Legislature intended the term "highway" in its more general meaning as applying to all public ways. This seems to be borne out by the decision in Graham v. Board of Public Works of Pittsfield, 285 Mass. 544.

As I construe the statute (G. L. (Ter. Ed.) c. 87, § 5) relative to the trimming, cutting or removal of public shade trees, it applies to town ways as well as highways, and the order to the tree warden may be given by the county commissioners, the city council of a city, and in towns, by the selectmen or road commissioners, whichever has jurisdiction of town ways.

> The "widening of a highway" in that section (5), and commonly, signifies a change in its location,— that is to say, its boundaries,— effected by bringing more of the earth's surface within that location, . . . Such "widening" is often comprehended within the broader term "alteration" . . . It requires the exercise of eminent domain. It is different in nature from a construction of a wider traveled or paved surface within the limits of the highway as already laid out.[50]

In Wright v. Chelsea, 207 Mass. 460, 464, in discussing the authority of the tree warden to trim trees, the court said:

> The discretion and sound judgment of the town tree warden alone determines whether a shade tree shall be trimmed . . . , and he is not subject to the control of the surveyor or road commissioners . . . It may be assumed that the Legislature made this provision in order that the trimming should be done, not by the road officer inexperienced in such matters, but by the scientific judgment of a forester or other official familiar with trees, and that thus the beauty and preservation of shade trees be conserved. At the same time it recognized that the safety of the travelling public is the paramount consideration, and placed upon the officer, charged with responsibility of maintaining all public ways reasonably safe and convenient for travel, the duty of determining whether any branches should be removed.

The implication of the provision in section 5, viz., "Nothing contained in this chapter shall prevent the trimming, cutting or removal of any tree which endangers persons travelling on a highway . . .", is that the tree warden is authorized to trim, cut or remove a tree if he determines as a fact that it endangers persons travelling on a highway.

Nothing in the statute shall interfere with the gypsy and brown tail moth suppression as carried on under the direction of the state forester and the United States department of agriculture, except so much as relates to the cutting and removal of trees, shrubs and growths that are more than one and one-half inches in diameter one foot from the ground.[51]

Violations of any of the requirements which I have herein discussed relative to the cutting, trimming or removal of public shade trees are punishable by forfeiture of not more than five hundred dollars to the use of the town.

The care and control of trees, shrubs and growths within a state highway are vested in the department of public works, and it may trim, cut or remove such trees, shrubs and growths, or license the trimming, cutting or removal thereof. No such tree, shrub or other growth shall be trimmed, cut or removed by any person other than an agent or employee of the department, even if he be the owner of the fee in the land on which such tree, shrub or growth is situated, except upon a permit in writing from the department. Any person injured in his property by the action of the department as to the trimming, cutting, removal or retention of any such tree, shrub or other growth, may recover the damages, if any, which he has sustained from the commonwealth under the eminent domain law. (G. L. (Ter. Ed.), c. 79). What I have previously stated with respect to the damages to land owners applies to damages which may result in the case of the trimming, cutting or removal of shade trees on state highways.[52]

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[49] G. L. (Ter. Ed.), c. 87, § 5.

[50] Graham v. Board of Public Works of Pittsfield, 285 Mass. 544, 547.

[51] G. L. (Ter. Ed.), c. 87, § 5.

In 1936, the Legislature authorized the department of public works to accept in behalf of the commonwealth from owners of land included in a strip one hundred feet deep bordering on a state highway voluntary gifts by deed or will of easements in such lands, giving the commonwealth the right to enter thereon at any time and in any manner for the purpose of landscaping such land by removing therefrom or re-arranging thereon vegetable growths and surface minerals, by setting out and planting thereon vegetable growths, by depositing thereon minerals, by re-arranging the contours of the land when deemed advisable, or by any or all of the foregoing methods. The department was further authorized to improve lands in which easements were so granted, "so as to carry out a comprehensive plan of highway beautification, artistic landscaping and scenic development, to the extent appropriations are available therefor."[53]

Penalties

The Legislature has not only provided a very definite procedure relative to the care, control, trimming, cutting or removal of public shade trees, but it has also provided substantial punishment for infraction of other provisions of chapter 87, such as the affixing to a tree in a public way or place, a notice, sign, advertisement or other thing, whether in writing or otherwise, or the cutting, painting or marking such trees, except for the purposes of protecting them and the public and under a written permit from the officer having the charge of such trees in a city or from the tree warden in a town, or from the department of public works in case of a state highway. The penalty provided is a fine of not more than fifty dollars. The tree warden is required to enforce this statute, but if he fails to act in the case of a state highway within thirty days after the receipt by him of a complaint in writing from the department of public works, that department may proceed to enforce this statute.[54] Severe penalties are provided for the trimming, cutting down or removing a tree, shrub or growth, within a state highway, or maliciously injuring, defacing or destroying any such tree, shrub or growth;[55] for the wilful, malicious or wanton cutting, destruction or injury to a tree, shrub or growth which is not his own, standing for any useful purpose;[56]

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[52] G. L. (Ter. Ed.), c. 87, § 8.

[53] G. L. (Ter. Ed.), c. 81, § 13A, added by St. 1936, c. 342.

[54] G. L. (Ter. Ed.), c. 87, § 9.

[55] G. L. (Ter Ed.), c. 87, § 10.

[56] G. L. (Ter. Ed.), c. 87, § 11.

for wantonly injuring, defacing or destroying a shrub, plant, tree, fixture or ornament or utility, in a public way or place or in any public enclosure, or negligently or wilfully suffering an animal driven by him or for him or belonging to him to injure, deface or destroy such shrub, plant, tree or fixture.[57]

It is to be observed that in sections 10, 11 and 12 of chapter 87 of the General Laws (Ter. Ed.), the words "maliciously", "wilfully", "wantonly" and "negligently" appear. In case of prosecution, it is not sufficient merely to show the commission of the offence, but it must be made to appear by competent evidence that the acts complained of were done "wilfully", "wantonly" or "maliciously" Each of these words indicate a state of mind, that is, the intent of the person against whom the charge is made. To do an act "wilfully", "maliciously" or "wantonly" there must be an intention to do so — a premeditation, so to speak. Where the offence charged is that of "negligently . . . suffers an animal . . . to injure or destroy a shrub, plant, tree or fixture" the negligence of the defendant must be shown. The test is, as in all cases involving negligence, what would the reasonably prudent man do in similar circumstances. The penalties provided in sections 10 and 11 are fines not exceeding five hundred dollars, or imprisonment for not more than six months; and in section 12, a fine not exceeding five hundred dollars. Civil liability also attaches in case of a violation of section 12.

SHADE TREES MAY CONSTITUTE DEFECTS IN A PUBLIC WAY

It has been held in numerous cases that shade trees may constitute defects in a way. In Valvoline Oil Co. v. Winthrop, 235 Mass. 515, 520, it was said:

> While many cases have been considered by this court involving injuries to travellers on a highway caused by trees standing within the limits of the way, most of them have arisen because of the decayed condition of such trees, . . . Yet we are of opinion that there is no sound distinction between the liability of a city or town for failure to guard against defects caused by trees within the limits of a highway which are old and decayed, and those which, although sound, in course of time cause a defective condition of a highway by growth. Anything in the state or condition of a highway which renders it unsafe for ordinary travel is a defect or want of repair.

In that case it appeared that the outer edge of the trunk of the trees was within six inches of the roadway, over which no portion of the trunk extended. A limb reached over the roadway, and grew from the trunk about seven feet from the ground. The circumference of the trunk at its base was approximately six feet four inches, and the limb at the trunk three feet six inches. The tree was about fifty years old, and at the time of the accident was in sound, healthy condition, including the limb in question. The plaintiff's wagon was damaged by the top of it coming in contact with the limb, and he was permitted to recover.

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[57] G. L. (Ter. Ed.), c. 87, § 12.

TREES MAY CONSTITUTE A NUISANCE

You will recall that in discussing the case of Jones v. Great Barrington,[58] I stated that the plaintiff, in another action brought by him to recover for the damages sustained by reason of a decayed tree's falling on his building, was permitted to recover. His recovery was permitted for the reason that the tree constituted a nuisance. In its decision of this latter case,[59] the court declared:

> In our opinion, upon the allegations in the declaration, the town, because of its title to the land within the limits of the public street, owed the duty to an adjoining land owner not to maintain a nuisance in the street to his injury. In Allegheny v. Zimmerman, 95 Penn. St. 287, 293, the court said: A public shade tree "may become a nuisance by disease or decay." In Gibson v. Denton, 38 N. Y. Supp. 554, 555, the court held that a decayed tree standing near the plaintiff's house, on which it might fall in any of the gales liable to occur, was a nuisance which the defendant on request should have abated. When such a nuisance exists in a public highway and the municipality has had notice thereof, it is not relieved of the obligation as a land-owner by the statute placing the control of public shade trees in the tree warden. Nor is it relieved from such obligation by reason of the fact that its duties with reference to the maintenance of public shade trees are public in their nature without pecuniary gain to it. The liability of a municipality as an "owner of land or of a building is the same as that of a natural person." . . . The municipality was in a position where it might take measures to protect a property owner in the position of the plaintiff from the harm which came to him.
>
> The liability of a town as an owner or in control of real estate does not rest upon the allegations of negligence . . . Its liability must rest upon the maintenance by it, upon land within its control, of a decayed and dangerous tree which at any time was likely to fall and for a substantial period of time had been so located as to expose the persons and property of others to the chance of instantaneous injury, and thereby became a "constant menace to the safety of the immediate community, and hence constituted a nuisance . . . when direct injury to an individual results, a private action can be sustained for damages suffered."

In concluding its opinion, the court further said:

> In our opinion, upon the allegations of count two of the declaration, the defendant could be found to have violated its duty to the plaintiff by maintaining a decayed and dangerous tree or in permitting it to stand after notice without taking action to protect the plaintiff and his property from injury from its fall.

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[58] 269 Mass. 202.

[59] Jones v. Great Barrington, 273 Mass. 485, 487.

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Tomato Leaf Mold as Influenced by Environment

By E. F. Guba

Knowledge of the life history of the tomato leaf mold fungus and the factors which favor infection is fundamental to an understanding of control measures. This bulletin deals with the various environmental factors which influence the development of the fungus and the infection of the tomato plant in the greenhouse.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

TOMATO LEAF MOLD AS INFLUENCED BY ENVIRONMENT

By E. F. Guba, Research Professor of Botany

INTRODUCTION

Tomato leaf mold, caused by the fungus *Cladosporium fulvum* Cke., has been the subject of numerous investigations, particularly in England, Germany, and the United States. For several years, the disease has been studied in Massachusetts in an effort to further knowledge of its control in the greenhouse. More recently, the work has been confined entirely to the development of suitable resistant varieties. It is the purpose of this paper to offer the results of studies dealing with the relation of environmental factors to the development and parasitism of the causal fungus, together with a comprehensive review of the pertinent literature. In view of the investigations now being pursued in different countries on the genetics of the tomato in relation to the parasite, the publication of these studies would appear opportune.

THE DISEASE

The reduction in yield and quality of tomatoes under glass as a result of the destruction of the foliage by the leaf mold fungus is familiar to every grower. The planting started late in the winter, which is designated the spring crop, usually shows signs of disease in the month of May. The disease gradually becomes epidemic as summer weather approaches. The second planting, started in July and August and designated the fall crop, is very seriously affected from the beginning, and usually by November, especially if the heating has been poorly managed, the foliage is destroyed except for a tuft of uninfected leaves on the tops of the trellised plants. The loss of foliage retards and checks the growth of fruit and reduces the volume and quality of the crop. This loss is much greater in the fall than in the spring. Usually, because of late incidence of the disease in the spring season of cropping, no real or apparent loss in yield is admitted.

The leaf mold fungus also causes a black stem-end rot of tomatoes. The rot results from the invasion of the fruit at the stem end by the mycelium of the fungus in consequence of spore infection of the blossom (9, 10, 13). When the blossoms and subsequently the ovaries are infected, the young fruits fail to develop and fall from the plants. The invasion of the more mature fruits with subsequent stem-end decay also makes possible the infection of the seed and the transmission of the fungus with the seed. This black stem-end rot is rare in Massachusetts greenhouses.

Seasonal climatic variations appear to govern the prevalence of the disease in greenhouses. In England the disease is most severe from May to August and only of slight importance from November to March (27, 31). In New Zealand there is no leaf mold for the first three to four months of growing, but with the occurrence of warm, wet weather in October and November, the disease may considerably damage the crop (6). In Massachusetts the disease is not restricted to greenhouse tomatoes. Its occurrence has been noted in epidemic form in outdoor plantings adjacent to greenhouses cropped to tomatoes and in stagnant areas associated particularly with uneven topography of the land and poor atmospheric drainage. The disease is of frequent occurrence in hotbed and cold-frame plantings here and elsewhere (23, 33), and in some years may appear as early as January on seedlings and plants for the first or spring planting in the greenhouse (23). It is reported to appear first and most seriously in the south and west sides, corresponding to the hottest parts of the greenhouse, and in east and west houses; and least in the north and east sides and in north and south houses (1, 7, 40). The lowest leaves become infected first. The occurrence and the epidemic development of the disease in definite situations and during definite seasons of the year, suggest the close association of the disease with particular environmental factors of light, temperature, and humidity.

THE FUNGUS

Careful life-history studies have never revealed more than the conidial stage of the fungus as it occurs on tomato foliage. Sclerotial bodies of the fungus have been noted in infected tomato seed (10), on corn kernels in pure culture (13), and as an overwintering stage which on the advent of spring produced conidia (3); but fruiting bodies of a perfect stage have never been observed (11). In the light of extensive observations and the unsuccessful efforts of other investigators to obtain the perfect stage, it appears that the fungus has never had the ability to produce pleomorphic spores. This fact has simplified the means possessed by the fungus for its survival and spread.

The conidia possess extraordinary resistance to extremes of environmental conditions which assures the occurrence of the disease from one year to the next. Plants have been infected with conidia from a leaf dried between blotting paper for six months, and after a period of one year some conidia were still viable (13). Spores exposed to a dry atmosphere for eight months were for the most part capable of germination; after ten months, only a small percentage was viable; and after twelve months none were viable (11). New spores have been observed to germinate in four hours; spores eight months old, in 24 hours. After being outdoors in a dry condition from January 4 to May 1, during which time the lowest recorded temperature was —4° F., spores germinated readily (32). Spores from overwintered leaves produce infection the following spring after passing severe winters on glasshouse structures and in the soil (27, 29).

The writer's experiments have shown that a large percentage of the conidia exposed under various temperature conditions was still viable after nine months. The death of the spores increases slowly with age. The fungus readily survives gaps between tomato crops in the greenhouse, and the source of the spores may be from the greenhouse itself or from the field.

The fungus has been grown on filter paper (13); on partially dead corn leaves; on detached tomato leaves (32); and on a decoction of tomato and tobacco leaves (11). This would suggest that the fungus exists on dead substrata in the absence of and apart from its susceptible living host, and that it is to be regarded as a facultative parasite.

The conidia of the fungus are disseminated chiefly by currents of air. The spores are easily dislodged from the leaves when the vines are disturbed in pruning and harvesting and by drafts of air, and are readily spread in the air throughout the greenhouse planting. Tapping or shaking the plants to assist in pollination of the blossoms, which is a usual and desirable cultural practice, dislodges clouds of spores into the air. The workers also collect spores on their clothing as they walk between the rows of plants and thus readily disseminate the fungus.

RELATION OF ENVIRONMENTAL FACTORS TO SPORE GERMINATION AND GROWTH

Relative Humidity

Makemson (13) reported good fungus growth at 97% relative humidity, excellent at 88%, poor at 75%, and none at 60%, on artificially inoculated plants under jars. In his experiments, these humidity values were maintained fairly well with sulfuric acid, but they were regarded as somewhat low due to the inaccuracies of the polymeter used. The optimum humidity for the fungus and the tomato plant were reported to be the same. Newhall (15, 16, 17) could not germinate the conidia below 96% relative humidity at room temperature, and reported that germination was best at 98 and 99%. In contrast, Rippel (22) found that at 40° and 68° F. spore germination was 100% at 95 and 100% relative humidity; 50 and 60% at 90% relative humidity, and none at 85%. He regarded the fungus as a xerophyte, and asserted that the spores were unable to germinate unless a positive moisture differential existed between the relative humidity of the air and the minimum hydration index of the spore, which he asserted to be 85% relative humidity. At an atmospheric relative humidity of 100%, the moisture available for swelling spores is maximum and offers the best chances for germination.

Studies were undertaken by the writer in an effort to obtain further convincing evidence. Conidia of the fungus were obtained from infected leaves and applied to glass slides with a camel's-hair brush. The tests were conducted under bell jars, and variations in the relative humidity of the air were obtained with different concentrations of sulfuric acid. Small tomato plants were placed with the slides under each jar. A Mason hygrometer was suspended in each jar and the entire equipment was incubated in controlled air temperature chambers. Readings of relative humidity were made frequently during the experiment. The conidia were incubated for periods of 24, 48, and 72 hours, and were thereafter placed in moist Petri dishes to make certain of their viability. The temperatures used ranged from 68°-72° F. In all the tests in which the spores were exposed to a relative humidity of 100% excellent germination occurred.

A film or drop of water is not required for germination, although the spores germinate excellently in this medium. In 20 tests in which the conidia were exposed to relative humidity values between 83 and 89% inclusive, there was no germination. In one series of experiments no germination occurred within a range of values of 90-95%. Germination was noted at 96% relative humidity and it was better at higher values up to 100% at temperatures of 68°-72° F. In another series of experiments in which temperatures of 78°-86° F. prevailed, germination occurred at 95 and 96% relative humidity; it was very poor at 94%; and there was only a trace at 90 and 92%. In other instances no germination was noted at 90%. Under the conditions of these experiments and under optimum temperature conditions for germination, a relative humidity of at least 95% is required for spore germination.

In other experiments, the spores of the fungus were applied to selected areas on the lower leaf surfaces of potted tomato plants. These plants were covered with open-topped bell jars plugged with cotton, in each of which was suspended a Mason hygrometer. The entire assembly was subjected to controlled temperatures. The relative humidity values were obtained with sulfuric acid. After an incubation of 72 and 144 hours, pieces of epidermis from the inoculated areas of the leaves were removed and examined under the microscope for spore germination, and subsequently placed in moist Petri dishes to determine spore viability. The results in Table 1 show that under optimum temperature conditions spore germination is extremely rare at relative humidity values of 90-95%. Values above 94% are favorable to germination, and a value of 100% is optimum. These results are closely in line with the findings of Newhall (15, 16, 17).

TABLE 1. RELATION OF RELATIVE HUMIDITY TO SPORE GERMINATION ON LEAVES OF TOMATO

Temperature °F.	Relative Humidity Percent	Spore Germination		Viability
		72 Hours	144 Hours	
78–80	100	Good	Good	Good
78–80	90–95	Rare*	Rare*	Excellent
77–80	90–95	Rare*	Rare*	Excellent
78–80	85–90	None	None	Excellent
78–80	71–80	None	None	Good
78–80	56–71	None	None	Excellent
61–63	100	Good	Good	Good
62–64	96–99	Fair†	Fair	Excellent
62–64	94–98	Fair†	Fair	Excellent
61–62	94	Rare*	Rare*	Excellent
61–63	82–88	None	None	Excellent
61–63	72–82	None	None	Good

*Short germ tubes
†Growth of germ tubes retarded

Temperature

The temperature relations of the fungus have received considerable study. Gardner (10) found that the minimum and maximum temperatures for growth and sporulation on potato dextrose agar are 35.6° and 95° F. respectively, and the optimum 68°-75.2° F. Caldis and Coons (5) reported no growth on Shives' dextrose agar at 50° and 86°-89° F. Makemson (13) asserted the minimum, optimum, and maximum temperatures for development of the fungus on the plant to be 48.2°, 68°-77°, and 86° F. respectively. Different opinions are reported concerning the relation of temperature to spore germination (Table 2). On the basis of the writer's study, spore germination occurred over a range of 40°-94° F. with the optimum at 75°-78° F. (Fig. 1). The optimum is considered the same as the most favorable day temperature for growing tomatoes under glass. Between 40° and 61° F. germination and the growth rate are slow. As the temperature increases from 79° to 94° F. the growth rate decreases rapidly.

Hasper (11) found that the spores are killed when frozen in ice at 2° F. for 7 days, but when left for the same period at a minimum temperature of about 8° F., a large part of the spores germinated. Spores sown in water at temperatures between 122° and 140° F. were killed. Dry air temperatures of 156°-158° F. for 4 hours were lethal, but after 3 hours some germination occurred. Exposure of spores to free winter weather for 3 months destroyed them. According to Spangler

TABLE 2.--TEMPERATURES AT WHICH SPORES OF *Cladosporium fulvum* GERMINATE

Authority	Temperature at which spores germinate		
	Minimum °F.	Optimum °F.	Maximum °F.
Bewley (4)		71 –77	90
Hasper (11)	32–33.8	68 –79.7	87.8–91.4
Makemson (13)	46.4	64.4–75.2	86
Small (26, 27, 30)	38	72 –77	89
Williams (39)		79 –81	90
Newhall and Wilson (15)	42.8		84.2
Alexander (2)		63 –70	90
Wollenweber (41)		68 –77	93.2
Gardner (10)	41	68 –77	95
Guba	40	75 –78	94

(32) winter weather from January 4 to May 1 at which a low temperature of —4° F. was reached did not affect the viability of the conidia. Judging from the epidemic occurrence of the disease from year to year, it seems that in Massachusetts, winter weather conditions have no adverse influence upon the fungus. Knowledge of the higher thermal death point would appear to have some practical application since high temperatures were advised in England in an effort to control the disease. Wright (42) and Thompson (35) advocated raising the greenhouse temperature to 110°-120° F. every second day for a week, and it is further noted

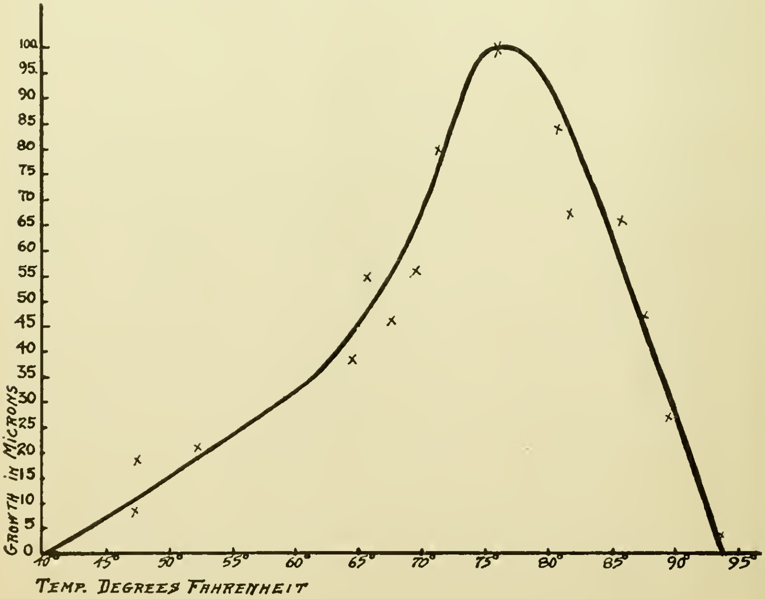

Figure 1. Relation of Temperature to Growth of Germ Tubes after 48 Hours Incubation

that a temperature of 100° F. for 2-3 hours at intervals of a week was offered as a valuable control measure (1); but Small (30) reported that the spores on diseased plants could not be killed by maintaining temperatures above 100° F. for several hours each day, nor when the maximum temperatures were made to reach 110°-130° F.

In the writer's studies on this question, the conidia were applied to glass slides with a camel's-hair brush and incubated in a dry atmosphere at temperatures of 100°-115° F. for different periods of time. After the designated period of incubation, the slides were placed in moist Petri dishes at optimum temperatures for germination to determine the viability of the conidia. It was shown that exposure for 2 hours to a temperature of 115°-116° F. destroyed their viability. At slightly lower temperatures, longer periods of exposure were required to kill the conidia (Table 3). At a temperature of 104° F. this was accomplished within 20-22 hours. From the results in Table 3, it is evident that a range of temperatures from 104°-115° F. is fatal directly in proportion to the period of incubation, when free spores are exposed.

TABLE 3.--PERCENTAGE OF GERMINATION OF SPORES OF *Cladosporium fulvum* AT DIFFERENT TEMPERATURES AND PERIODS OF EXPOSURE

Temperature °F.	Percentage of Germination After Exposure of —										
	2 Hr.	4 Hr.	6 Hr.	8 Hr.	10 Hr.	12 Hr.	14 Hr.	16 Hr.	18 Hr.	20 Hr.	22 Hr.
115.........	–										
110–112.......	†	Tr.	–								
109–110.......	75	Tr.	–								
107–108.......	75	14	4	–							
105–106.......				25	10	6	2	–			
104.........					80	48	25	11	4	Tr.	–

†Germination
–No germination
Tr. Trace of germination

Subsequently, small diseased potted plants were exposed to temperatures of 108°-110° F. for different lengths of time. Germination was not affected by an exposure of 2 hours, but was reduced about 75% by an exposure of 4 hours, and about 90% by an exposure of 6 hours. Injury to the foliage, especially tender and diseased areas, occurred in each instance and increased in severity with the duration of exposure. Further experiments were conducted in a greenhouse of 1,000 square feet with matured tomato plants on which infection was epidemic. On one occasion temperatures ranging from 105°-110° F. were maintained for 2 hours; on another, 118°-123° F. for 3 hours. The plants were injured by the latter treatment but spore germination was not appreciably affected.

Light

Light has a retarding influence on the growth of the spore germ tube, and is unfavorable to the best growth of the fungus in culture (13). According to Volk (36), bright light causes a rich growth of spores on the leaves, and darkness favors rapid vegetative growth. Hasper (11) noted that several hours exposure to direct sunlight is lethal to the spores.

The influence of light on spore germination was considered by the writer in a series of experiments. Fresh spores of the fungus were brushed on glass slides and incubated in Petri dishes containing moist filter paper. One set of slides in each experiment was placed in a black light-proof box; another set received only daylight; and a third set was exposed throughout the total period of incubation to artificial light of a 60-Watt Mazda daylight lamp, but far enough from it to escape a lethal temperature influence. The details of the experiment and the results are presented in Table 4. Continuous darkness was more favorable for germination and growth than a combination of daylight and night darkness. Light definitely retarded and suppressed spore germination and growth.

Table 4. Effect of Light on Spore Germination and Growth in Length of Germ Tube

Experiment	Temperature °F.	Exposure Hours	Continuous Darkness		Day and Night		Continuous Light	
			Germination	Growth, Microns	Germination	Growth, Microns	Germination	Growth, Microns
1	60–70	24	Good	33.4	Poor	18.3	None	0
	60–70	48	Good	58.3	Poor	49.6	None	0
	60–70	72	Excellent	83.1	Fair	65.8	Trace	32
2	60	24	Good	19.9	Good	13.6	Poor	8.1
	60	48	Good	25.6	Good	22.3	Poor	14.7
3	60–70	57	Excellent	70	Fair	55	None	0
4	60–70	120	———	94	———	72	———	66
5	70	48	Good	72	Poor	49	Trace	26
6	60–70	24	Poor	32.6	Poor	35	None	0
Average				54.3		42.3		16.3

INFECTION PHENOMENA

Method of Infection

Infection of the foliage and the green floral structures is entirely through the stomata, and this manner of infection is believed to be due to a chemotactic stimulus within the stomata exerted upon the germ tube (11, 13). Stomata are present on both surfaces of the tomato leaf, but their numbers are much greater on the lower surface. According to Small (29, 30), infection may occur on either surface of the leaf, but inoculation of upper leaf surfaces produced leaf mold only on the lower surfaces. Makemson (13) obtained successful infections on both leaf surfaces but more on the lower surfaces. Caldis and Coons (5), using bits of mycelium from pure culture, succeeded in infecting leaves only by inoculations of the lower leaf surfaces.

In the writer's experience, the fungus always develops on the lower leaf surfaces first, but in the later and final stages of the disease the upper leaf surfaces also become densely covered with the fungus. Under natural conditions of inoculation the older terminal leaflets are always the first to become infected, but according to Small (29), leaflets of various ages are equally susceptible, and this conclusion is substantiated by the writer's inoculation experiments. According to Makemson (13), the germ tube may immediately enter a stoma but usually considerable growth in length takes place before penetration. He noted cases of penetration 36 hours after inoculation. Williams (39) found that penetration had not occurred within 39 hours and concluded that a long period elapsed before penetration takes place. Hasper (11) observed that penetration usually required 4 to 8 days, while 10 to 12 days were required in other instances.

The writer's studies point to the importance of stomatal numbers and diameter in infection. It was observed that under greenhouse conditions the stomatal openings on the lower leaf surfaces are larger and the stomata much more numerous (11), and open over much longer periods each day of 24 hours, than on the upper leaf surfaces. The presence of infection only on the lower leaf surfaces in the beginning of epidemics is evidence of the significant relation of stomatal openings and numbers to infection. It has been asserted that plants in the open have fewer stomata than plants in the greenhouse (6) and that this is one factor accounting for the less frequent occurrence of the disease in the open. No differences in stomatal numbers were apparent from the writer's examinations of greenhouse and outdoor plants of the same variety.

Soil Moisture

Small (27, 31) noted that turgid plants become infected more readily than drooping plants, and observed that spores on drooping foliage failed to germinate. The higher humidity around turgid leaves permitted germination and infection. The belief prevails that artificial forcing conditions influenced by high temperatures, excessive moisture, and fertilization, greatly increase the susceptibility to disease, while more natural conditions in the open are less inducive to infection (14, 19). Volk (36) found no difference in the susceptibility of the leaves of plants growing in soils with moisture between 50 and 80% of the water-holding capacity. On wilting plants growing in a soil containing 25-30% moisture the incubation period was prolonged, fructifications were more abundant, and the viability of the fungus was extended.

Both turgid and wilting tomato plants were inoculated by the writer on August 16. On August 20 germination on the turgid foliage was considerable, the germ tubes were up to 80 microns in length, some capped with appressoria as noted by Makemson (13), and some tubes already lodged in the stomatal cavities. No branching of the tubes was evident. The tips of many of the tubes were lying directly over the closed stomatal cavities. In contrast to this condition, wilting plants inoculated at the same time and maintained in a wilting condition showed no evidence of spore germination by August 22, and when examined frequently the stomata on both leaf surfaces were tightly closed. On September 7 the foliage of the turgid and wilting plants was examined for infection (Table 5). The difference in the number of leaflets available for counting was due to the vast difference in growth associated with these extreme soil moisture conditions.

In another experiment the lower leaf surface of turgid and wilting plants grown in ground beds in the greenhouse was inoculated on August 18. Examinations of foliage 48 hours after inoculation revealed no spore germination on wilted plants growing in dry soil, but an abundance of it on turgid plants growing in moist soil in the same greenhouse; and the same condition existed on August 22. A deficiency of moisture sufficient to induce a flaccid condition of the leaf causes the

TABLE 5. INFLUENCE OF TURGIDITY OF FOLIAGE ON INFECTION

	Total Number of Leaflets	Infected Leaflets Percent
Turgid Plants		
1	111	23.4
2	84	33.3
3	84	33.3
Flaccid Plants		
1	63	0
2	46	0
3	52	0

closing of the stomata. The wilting plants were subsequently maintained under soil moisture conditions making for turgidity, and at the end of 48 hours considerable spore germination was noted. Next to light, the moisture supply of the leaves is the factor which most universally affects the opening or closing of the stomata. Turgidity, therefore, contributes to the conditions necessary for infection. Open stomata and respiration are definitely correlated with turgidity and give rise to a greater local humidity. The greater amount of tissue disorganization and fungus mycelium in the spongy parenchyma and about the tracheary tissue than in the palisade parenchyma in newly infected leaves suggests that conditions in the spongy parenchyma play a part in the preponderance of infection on the lower leaf surfaces.

Both Dyke (7) and Weiler (38) have noted that tomatoes are attacked by leaf mold in new houses more readily than in old houses. Dyke declared that tomatoes do not take the disease as readily under shaded as under clear glass, on the assumption that glass which allows more heat and light to pass is more favorable to the progress of the disease. According to the writer's observations, new greenhouses in locations outside of vegetable trucking areas are usually free of leaf mold for the first one or two years of growing, because of the absence of nearby sources of the fungus. In established trucking districts epidemics of leaf mold of equal severity have been noted on the first cropping of tomatoes in new and old greenhouses.

Bright sunlight is regarded as a lethal or unfavorable factor. It is reported that the disease develops earliest and best in parts of the house made hottest by the sun, corresponding to the south and west sides, and some reports appear to attribute this to light. Around Cleveland, Ohio, houses built north and south are reported to be freer of the disease than east and west houses (2) because in the former more sunlight is allowed to penetrate between the rows and temperature fluctuations from sunlight are less rapid and severe. Makemson (13) noted that dark, cloudy days furnished ideal conditions for the disease. Volk (36) found that tomatoes were more seriously diseased in darkness than in light. The toxic influence of light on fungous pathogenes of plants in greenhouse culture was recognized by Stone (34).

Since infection is obtained only under conditions which favor the opening of the stomata, light is an important factor for infection; and since the stomata close in darkness infection does not occur at night. Infection on the upper leaf surfaces is handicapped by the lethal influence of strong sunlight on the fungus itself. Temperature and humidity operate more favorably for spore germination on the lower shaded leaf surfaces. When the sun is shining brightly, the temperature is obviously lower on this side of the leaf than on the upper surfaces, and the air is not as dry as that adjacent to the upper surfaces.

Conditions at the leaf surfaces are vital to the infection process. This is shown by the results of the writer's inoculations of upper and lower surfaces of leaflets with dry spores applied with a camel's-hair brush in mid-August in the greenhouse, at a time when warm temperatures and strong light conditions prevailed. No germination occurred on the upper lighted leaf surfaces but it was abundant on the lower shaded surfaces.

Langford (12) noted greater susceptibility to infection with less light and asserted that the genetic factor for resistance disappeared with the lack of light. The inherent resistance of the Stirling Castle tomato to one strain of *Cladosporium fulvum* was but slightly expressed during midwinter at Toronto, Canada, and accordingly varieties resistant during the summer season can be susceptible during midwinter. This has not been the case in the writer's experience, nor are any similar instances on record. Infection among susceptible varieties requires very specific conditions of host and environment. Variation in the occurrence of the disease closely follows differences in those fundamental environmental factors which influence stomatal movements and spore germination. Proper incubating conditions for infection are necessary to determine the true reaction of the variety. Varieties and hybrids of *Lycopersicum esculentum* reported to possess resistance have become badly diseased under conditions favorable for infection and have for that reason been abandoned as a source of resistance in this work. Even admitting the possibility of strains of the fungus, the conflicting reports asserting the type of reaction of "esculentum" tomatoes to *Cladosporium* cannot be taken too seriously. Susceptible varieties, including Stirling Castle, or hybrids of parents showing some resistance in the summer months have manifested little if any disease in midwinter in the greenhouse, and this is due to fundamental influences of temperature and relative humidity at the leaf surfaces, which are more favorable for the fungus at one season than at the other, and not to a host reaction that is genetically plastic to infection with changes in the light experience of the plants.

Nutrients

The relation of nutrients to the susceptibility of tomatoes to infection has been given considerable study abroad but there is no consistency in the results. Schaffnit and Volk (24, 25) and Volk (36) found that outstanding resistance was manifested by plants having deficient supplies of phosphoric acid or nitrogen, and that the lack of phosphoric acid devitalized the fungus sufficiently to render it less viable and infective. Superfluity of nitrogen, deficiency of potash, or excessive application of all the constituents rendered the plants very susceptible. Intermediate manifestations were shown when the plants were given normal quantities of all the constituents, or an excess of potash and phosphoric acid. Fleischmann (8) found that the development and extension of the parasite was greatly increased on overnourished plants and that deficiencies of important nutrients caused both weak plants and a check in the growth of the fungus. He found that acid phosphate and potash lacked the effect of increasing resistance, and that susceptibility and immunity are varietal manifestations which are not essentially influenced by nutrition. Small (29) noted a severe development of leaf mold on manured plants, while on starved plants the infected leaf areas remained small and bore comparatively little of the fungus. Reusrath (20) cautioned against the use of excess or unbalanced nitrogen and advocated the liberal use of potash as a means of moderating the susceptibility of the tomato to disease. According to Rice (21) superphosphate has an encouraging effect, and potash and nitrogen a retarding influence.

These opinions cannot be taken too seriously in view of the fact that the chief objective of the grower is a high yield of quality fruit. Plant vigor is a prerequisite to success and obviously is obtained by proper fertilizer balance, soil moisture, temperature, and humidity. The opinions reported above are based largely on sand and peat cultures supplied with different ratios of potash, acid phosphate, and nitrogen; and the effect on yield and quality of the fruit appears to have been of minor consideration. Further, the tomato is susceptible to several physiological disorders such as blossom end rot, growth cracks, puffiness, hollow stem, blotchy ripening, greenback, edema, etc., which are associated with malnutriton, weather, and soil moisture. The suggestion of Volk (36) that more effort should be directed to provide environmental conditions which render the host less favorable to infection, rather than those which affect the activity or suppression of the parasite, disregards the resulting danger from other abnormalities which may prove more serious than leaf mold. Neither have conditions influencing weak or vigorous growth or the presence or absence of any of the abnormalities mentioned above shown under commercial conditions observed by the writer any apparent influence upon the susceptibility of tomato plants to leaf mold. The proper fertilizer amendments to the land, soil moisture, and temperature, to obtain plant vigor are vital to a successful yield, and any contrary practices employed as a means of counteracting a particular limiting disease factor are unwise.

Chemical or Induced Immunization

Efforts have been made to immunize the leaf tissues to infection by introducing chemical substances into the roots. In some experiments reported by Massee (14), tomato plants were immunized to Cladosporium by watering every three days from two to six weeks of age with a solution of copper sulfate (1-7000). After six weeks, the plants were watered every fourth day with a stronger solution (1-6000). None of the plants given the copper sulfate showed leaf mold.

Norton (18) used similar and weaker solutions of copper sulfate. Injury occurred except at a dilution of 1-10,000 but plants so treated developed Cladosporium in five days. The results from applying chemicals through stems or roots were in general negative. Hasper (11) also reported negative results. In view of these findings and the lack of practical application, no consideration has been given to this phase of the problem in this study.

Relative Humidity and Temperature

Volk (36) obtained the highest number of successful inoculations at 95% relative humidity. According to Bewley (4) and Small (26, 27, 28, 31), infection is slight or rare at an optimum growing temperature of 72° F. at 70-71% relative humidity, but severe at 80% and higher. At 58% and less despite an optimum growing temperature, or at temperatures less than 59° F. despite a favorable relative humidity, the fungus is suppressed or develops very slowly.

Rippel (22) declared that average relative humidities are insufficient for a proper analysis of the problem and that values less than 85% for 18 to 20 hours each day are necessary to check or prevent the disease. Walker and Sumner (37) declare that relative humidities around 80% and lower are against infection, while continuous exposure for 48 hours, or for a 2-hour period each day for 14 consecutive days, to relative humidities above 80% promotes infection. Alexander (2) found that very little infection occurs when plants are exposed for less than 9 hours in a saturated atmosphere at 59°-85° F. In clear weather, in early spring in Ohio, the greenhouse air is saturated usually less than 8 hours daily so that infection does not occur. From late spring to November, high humidities prevail for a long time and infection is epidemic. A significant concept is expressed by Newhall and Wilson (16) and Newhall (17) to the effect that relative humidities of 90-96% prevail at the leaves even though the greenhouse air may be as low as 75% and that this is due to leaf transpiration. The coincidence is noted of the disease being most severe when the transpiration rate is the highest or when the average house temperature is above 65°-70° F.

In greenhouse tomato culture in Massachusetts, the leaf mold disease appears in May, is epidemic during the summer months, and gradually subsides after October if the heating is properly managed. Bad attacks of the disease in August and September cause the fungus to persist throughout the autumn season especially if the weather is mild. The greenhouse mean maximum temperatures rise above 90° F. and prevail there from late June to mid-August, then recede to about 65° F. in December (Fig. 2). The outside mean maximum temperatures reach the highest (75°-80° F.) and the lowest (32°-34° F.) levels in the corresponding periods. The influence of high temperatures on leaf transpiration which supplies the moisture necessary for spore germination must be conceded. From May to October inclusive, pipe heating is either irregular or discontinued since greenhouse temperatures prevail above or close to the minimum temperatures for satisfactory growth (Fig. 3). This situation renders the prevention of high relative humidity in the greenhouse difficult if not impossible during this critical period, even with ventilation. After this period, beginning with October, the increasing gap between the inside and outside temperatures, reaching a maximum of almost 45° F., effects a corresponding decrease in the mean relative humidity which is at the lowest level in the months of December, January, and February, corresponding to the widest differences in temperatures. As the season advances, the gap between the outside and inside mean minimum temperatures becomes extremely narrow, being the smallest, or less than 5° F., from June to September inclusive. This temperature differential, directly as it affects the relative humidity, is a major influencing factor governing the behavior and progress of the disease in the greenhouse. The usual failure of the fungus to sporulate on the leaf surface in the winter months is due to the prevailing low relative humidity (27, 36).

The average mean and mean maximum relative humidity under glass are shown graphically in Fig. 4. These reach peak levels from May to September inclusive, corresponding to the highest monthly mean temperatures. During this period the average mean relative humidity inside is about 80-82%, and the mean maximum 100%. At the leaf surface, due to a high transpiration rate under these conditions, the relative humidity is usually near, or at, 100%. The more abundant application of water to the soil in the warmer months, and its influence on the humidity of the greenhouse air, must also be recognized. Since temperatures of 74°-79° F. and relative humidities of 98-100% are optimum for spore germination and infec-

FIG. 2

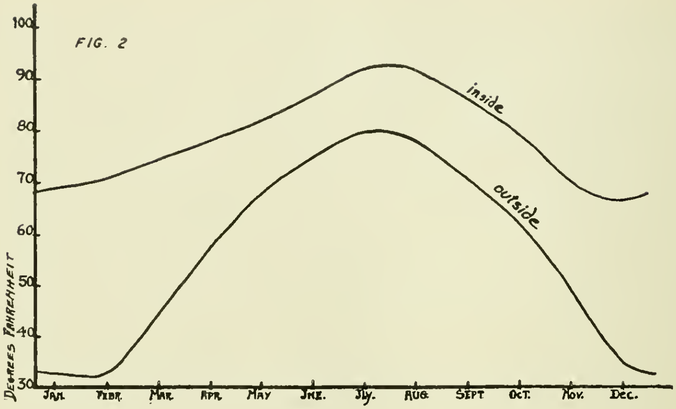

FIG. 3

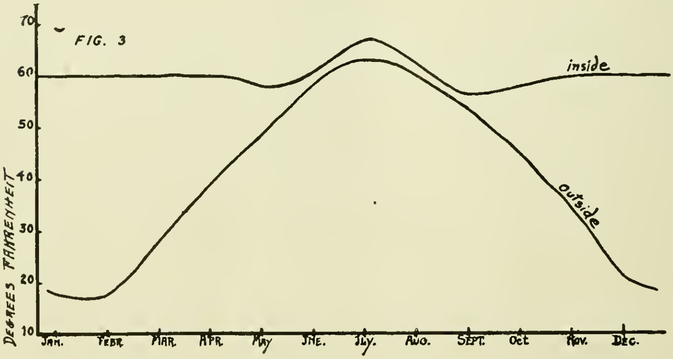

FIG. 4

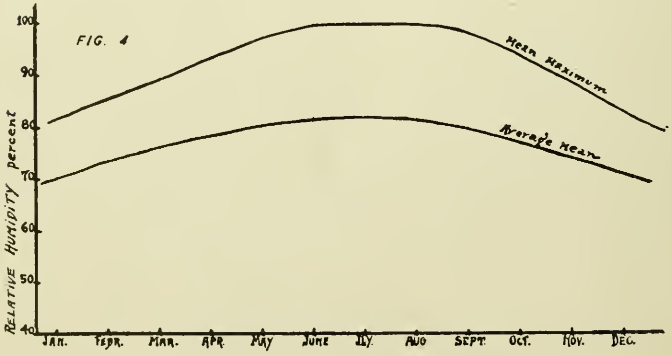

Figure 2. Approximate Course of Monthly Mean Maximum Temperature in Tomato Culture under Glass and in the Open in Massachusetts

Figure 3. Approximate Course of Monthly Mean Minimum Temperature in Tomato Culture under Glass and in the Open in Massachusetts

Figure 4. Approximate Course of Monthly Mean Relative Humidity in Tomato Culture under Glass in Massachusetts

tion, it is obvious that at this season ideal temperature and moisture conditions for the fungus prevail.

A clearer understanding of temperature and humidity conditions prevailing under glass in the culture of tomatoes in Massachusetts may be obtained from a study of some of the weekly record charts. Under summer weather conditions day temperatures often reach 95° F. and higher, in spite of ventilation, and the minimum temperature is hardly ever below 60° F. A peak relative humidity of 100% prevails almost every night (Fig. 5-A). In bright weather and with ventilation, the relative humidity values in the greenhouse recede with rising temperatures, and the lowest relative humidity values are associated with the highest air temperatures. These are the conditions of the air some distance from the leaf itself. At the leaf surface higher humidity prevails. The records of temperature and relative humidity outside the greenhouse for the week ending September 30, 1929, show the same wide fluctuations in night and day conditions (Fig. 5-B). Moisture saturation with the lowest temperatures prevails at night, and the lowest relative humidities (below 50%) with the highest temperatures occur at midday. It is evident, as Rippel (22) noted in Germany, that the relative humidity in the greenhouse is above 80% for much of the day, and only for a short time under 60% in the off or mild heating season.

With the beginning of the boiler heating season in September and October, some influence of heat on the humidity of the greenhouse air (Monday and Tuesday, Fig. 6-A) is shown; while lacking heat (Wednesday to Sunday) a relative humidity of 100% prevails regularly in spite of ventilation. At this season, the temperature difference between the inside and outside air is so small, or zero, that there is usually little if any effect from boiler heat on the humidity of the greenhouse air, even when supplemented with ventilation, unless the temperature is raised unreasonably high. The influence of heat on the humidity of the air is thus clearly demonstrated in Fig. 6-A, 6-B, and 7-B.

During cold winter weather and with the greenhouse temperatures maintained at and near 60° F., the wide fluctuations of temperature and humidity prevailing during the warmer months are smoothed off to rather narrow limits (Fig. 7-A and 7-B) except when periods of warm weather interrupt to cause the outside temperature to converge closely upon the minimum inside growing temperature. These periods introduce high relative humidities which may be controlled by proportionately higher temperatures. The need for ventilation supplementary to heat at these times is significant.

To obtain more intimate knowledge of the problem, frequent readings of the Mason hygrometer and psychrometer were made in different locations in the greenhouse at, and away from, the foliage and with different outside weather conditions and amounts of ventilation. A set of readings was taken on a rainy day in April when the outside temperatures were 42° to 52° F. and the relative humidity 100%. A rotary fan was operated 6½ feet from the ground and in the center of a greenhouse of 10,000 cubic feet (Table 6). Without ventilation and with the particular outside conditions prevailing when these readings were taken, the relative humidity at the foliage was 100%; at the ground between the rows of plants 83 to 88%; and at the fan 83 to 88%. Inside temperatures were in the range of 60° to 70° F. In these instances, the air re-circulated by fanning lacked sufficient evaporating power to influence the relative humidity at the foliage. Obviously, the greenhouse air must be changed with much drier outside air, or diffused with much colder outside air and heated, to obtain an appreciable reduction of the relative humidity.

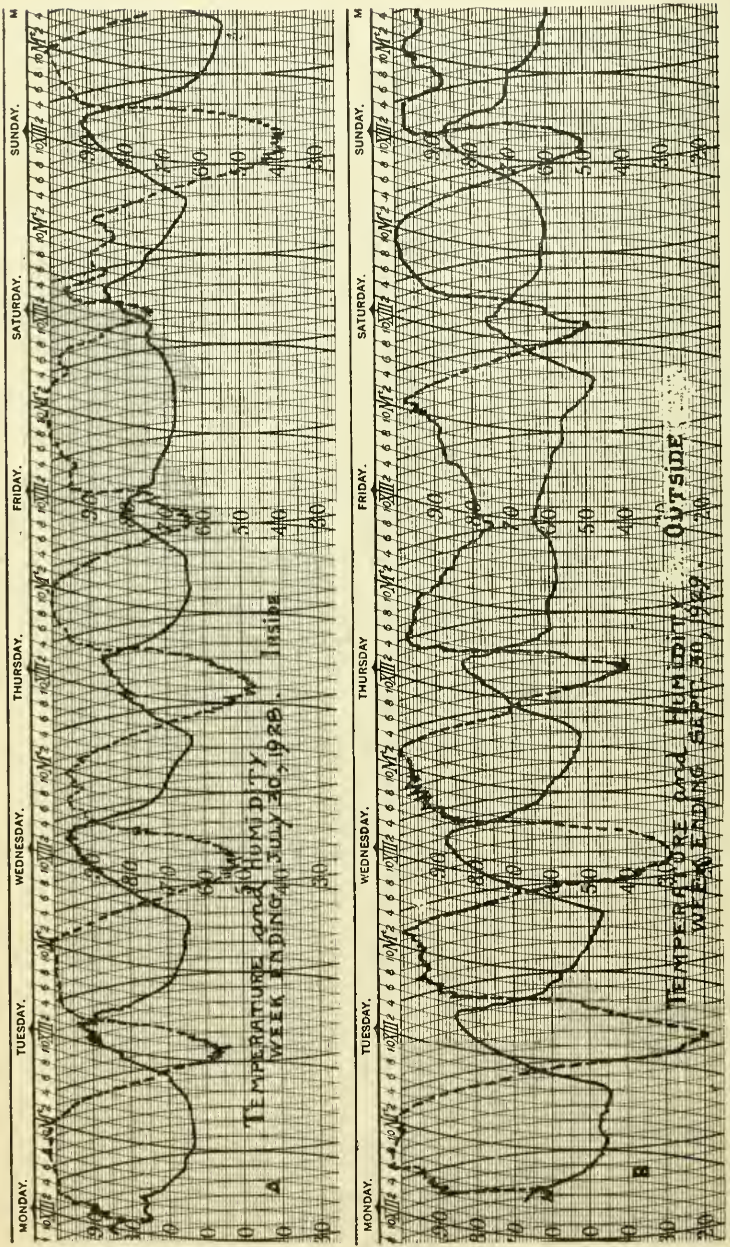

Figure 5. Instrument Records of Temperature and Humidity
A, in the greenhouse; B, outside the greenhouse
Temperature ——— Relative Humidity – – – –

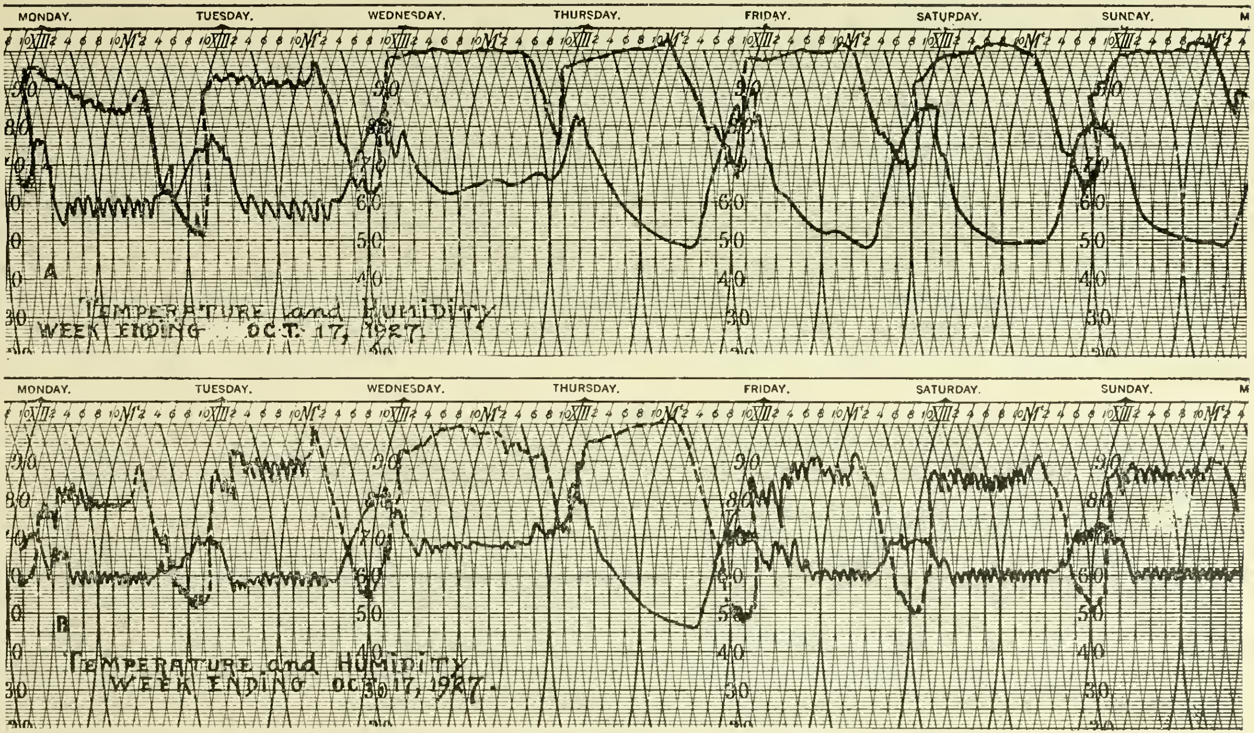

Figure 6. Instrument Records of Temperature and Humidity in Two Separate Greenhouses
Temperature ——— Relative Humidity - - - - - -

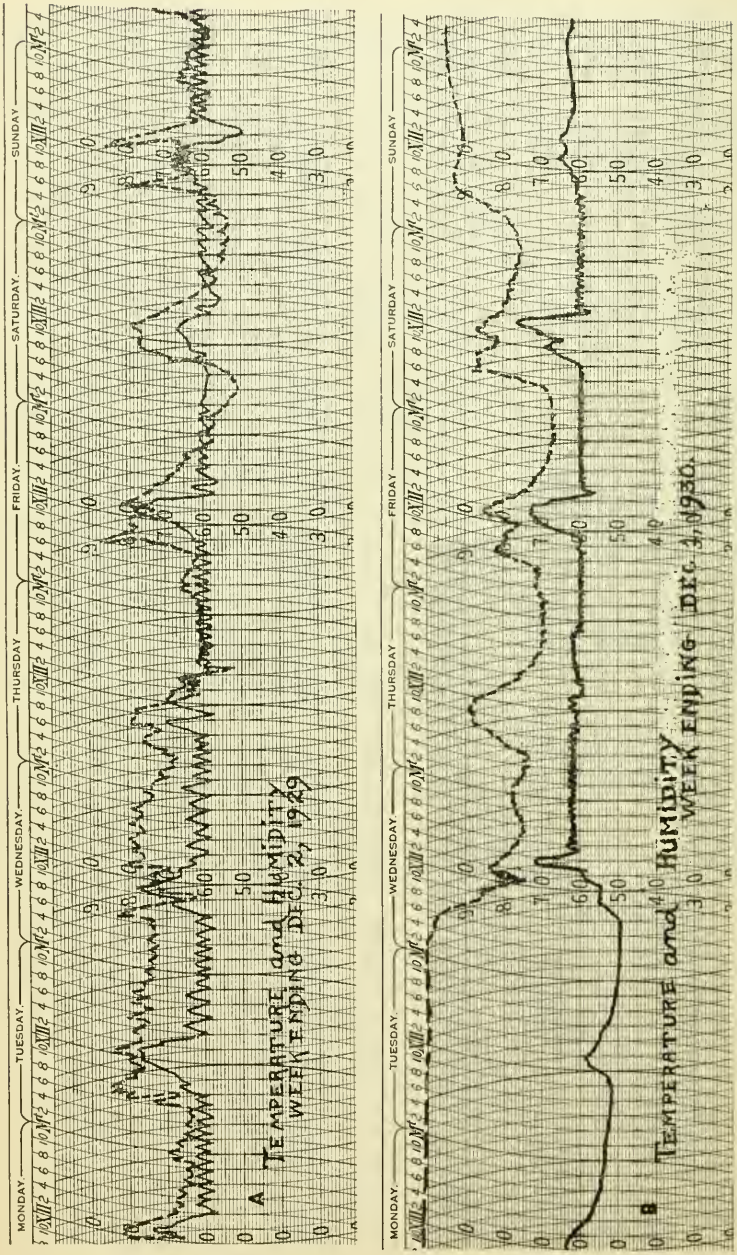

Figure 7. Instrument Records of Temperature and Humidity in the Greenhouse
Temperature ——— Relative Humidity - - - -

TABLE 6.--TEMPERATURE AND RELATIVE HUMIDITY IN GREENHOUSE PLANTED TO TOMATOES

(Readings on rainy day in April, 1929: outside relative humidity, 100 percent)

Air Temperature °F.	Relative Humidity Percent	Hour	Position of Hygrometer
64	82	8:45 a.m.	In corner near plants
65	83	8:45 a.m.	At fan
64	88	9:00 a.m.	In corner near ground
67	88	9:00 a.m.	At fan
64	88	9:00 am..	Between rows near ground
68	100	9:30 a.m.	At foliage
69	83	9:30 a.m.	At fan
70	88	10:00 a.m.	Between rows 8 inches from ground
70	83	10:00 a.m.	At fan
69	100	10:30 a.m.	At foliage
70	83	10:30 a.m.	At fan
70	88	11:00 a.m.	In draft halfway between fan and ground
70	88	11:00 a.m.	Between rows 8 inches from ground
68	100	11:00 a.m.	At foliage
69	83	11:00 a.m.	At fan

This is substantiated further by another set of readings (Table 7) obtained during rainy weather and when the greenhouse atmosphere was stirred by ventilation rather than by the motions of an electric fan. As the readings reveal, the influence of ventilation during wet weather conditions outside on the relative humidity inside is quite insignificant in the absence of heat. Under these conditions, the air at the leaf surface is saturated with moisture.

TABLE 7.--TEMPERATURE AND RELATIVE HUMIDITY IN GREENHOUSE PLANTED TO TOMATOES

(Readings in moist, cloudy weather)

Ventilation	Hour	Away from Foliage		At Foliage	
		Air Temperature °F.	Relative Humidity Percent	Air Temperature °F.	Relative Humidity Percent
All ventilators and doors open	4:00 p.m.	68	88	66	100
All ventilators open .	2:00 p.m.	62	100	61	100
All ventilators and doors open	8:00 p.m.	64	94	63	100
Top ventilators open	9:00 a.m.	62	100	61	100
Top ventilators open	2:00 p.m.	71	88	70	100

In contrast to the previous tests, readings were taken under prevailing bright weather conditions in May, October, and November (Table 8) when ventilation was provided from the top and sides of the greenhouse. These readings show higher relative humidities and lower temperatures at the foliage than in the open atmosphere between the rows of plants. The introduction of drier outside air by ventilation reduces the relative humidity at the foliage, and the reduction is greatest when both the top and side ventilators are opened. Previously it was shown that saturated moisture conditions prevail at night during the warmer months. It is also evident that relative humidities above 95%, accompanied by optimum temperatures for the fungus at the leaf surfaces in consequence of high rates of transpiration, are of common occurrence during the day throughout the warmer months in spite of ventilation.

TABLE 8. TEMPERATURE AND RELATIVE HUMIDITY IN GREENHOUSE PLANTED TO TOMATOES

(Readings in bright weather in May, October and November. Ventilators Open.)

Away from Foliage		At Foliage	
Air Temperature °F.	Relative Humidity Percent	Air Temperature °F.	Relative Humidity Percent
61	74.5	58.5	96.5
62.5	80	62	94
66	83	63	97
67	73	63	91
71	73	70.5	97
71	78	68.5	91
83	64	74	89
85	61	80	85
84	72	80	85
87	65	83	100
88	61	84	85
89	73	82	98
90	62	84	85
94	60	90	81

Newhall and Wilson (16) and Newhall (17) asserted that with rapid air changes a relative humidity as high as 90% in the greenhouse may exist without infection. With infrequent air changes a relative humidity as low as 60% would be required to prevent infection. They noted that in a stagnant atmosphere infection proceeds when the greenhouse air is as low as 80% relative humidity. The writer's readings reveal that the recirculation of air of high relative humidity and of nearly similar temperature does not influence humidity conditions at the leaf surface and has little effect on the humidity of the air itself. The infiltration of cold outside air and warming it to maintain a minimum growing temperature of about 60° F. produces a drying greenhouse atmosphere and this condition is most pronounced in the coldest months of the year. In the warmest months of the year the introduction and free circulation of outside air of real low relative humidity produces the greatest evaporating effect at the leaf surface. Between these extremes of maximum heating in the winter and maximum evaporation from ventilation in the driest summer weather, favorable conditions for infection commonly occur in the greenhouse which, even in spite of heat or natural and forced ventilation or both, and within the limits of good plant growth, are often beyond any reasonable or practical means to counteract.

Small (26) noted the most progressive development of the disease in July and August, the warmest months, in England and when air saturation occurred in the houses at night. The evidence fully substantiates the view that seasonal variations in the severity of leaf mold are related fundamentally to temperature (16, 17, 27), other conditions being favorable for good growth of the tomato plant.

SUMMARY

In greenhouse tomato culture in Massachusetts, the leaf mold disease is usually epidemic from June to October. It occurs in field plantings near greenhouses and in areas of uneven or sheltered topography and poor atmospheric drainage. The fungus is a facultative parasite.

Only the conidial stage of the fungus is known. The spores withstand severe winters and remain viable under the most adverse conditions for 9 to 12 months. Conidia are disseminated by air currents and are readily dislodged by shaking or disturbing the plants.

A relative humidity of 100% or precipitated moisture and temperatures of 75°-78° F. are optimum for germination. A relative humidity of 95-96% is minimum and 40° F. and 94° F. are the minimum and maximum temperatures for spore germination. Conidia lose their viability when exposed to a temperature of 115°-116° F. for 2 hours. Longer exposures at slightly lower temperatures are also lethal. The exposure of infected plants for 3 hours to 118°-123° F. does not affect germination of the fungus appreciably and is injurious to the tomato plant.

Light retards growth and suppresses spore germination. Strong light is lethal to the spores.

Infection is through the stomata, usually or entirely in the lower sides of the leaves where the stomata are most numerous and where conditions within the leaf and light, temperature, and relative humidity at the leaf surface operate more favorably for spore germination than at the upper leaf surfaces.

Open stomata and transpiration are associated with light and turgid growth. Flaccidity of the foliage, brought on by a moisture deficiency in the leaves, and darkness operate to close the stomata and to hinder infection.

Conditions at the leaf surface are fundamental to the infection process, and variations in the occurrence of the disease in the greenhouse at different times of the year are due to fundamental environmental factors operating to favor or prevent spore germination on the leaf.

Plant vigor is a necessary asset to high yields and quality, and the result of good growing conditions. Efforts at modifying the nutrition of the plant to influence the reaction of the host in the direction of resistance are not practical or commercially successful. Immunization of the host with chemical solutions applied to the soil has not proved safe or successful.

The disease is epidemic during the warmer months from June to October inclusive, when maximum greenhouse temperatures of 80° to 92° F. prevail; when the mean minimum inside and outside temperatures converge to a narrow difference of less than 5° F.; and when the highest mean maximum relative humidity of 94-100% for the year prevails. The influence of high temperature on leaf transpiration and infection is recognized. The severity of the disease is related fundamentally to temperature.

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Germination of Seeds and Damping-off and Growth of Seedlings of Ornamental Plants as Affected by Soil Treatments

By William L. Doran

Heavy losses from damping-off, commonly experienced, have aroused interest in more practical methods for control and prevention. This bulletin reports results from recent investigations in this field.

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GERMINATION OF SEEDS AND DAMPING-OFF AND GROWTH OF SEEDLINGS OF ORNAMENTAL PLANTS AS AFFECTED BY SOIL TREATMENTS

By William L. Doran, Research Professor of Botany

INTRODUCTION AND METHODS

The production of ornamental plants is an important industry in Massachusetts, receipts from their sales comparing favorably with receipts from such other leading crops as apples, tobacco, potatoes, and onions; and there are, of course, many amateur gardeners in the State for whom gardening is a recreation.

As is well known both to professional plantsmen and to those who find in gardening an avocation, a principal problem in the propagation of plants from seed is the damping-off disease by which germination is injured and seedlings weakened or killed. This disease, too generally recognized to need description here, is controllable by known methods of soil disinfection; but it is doubtful whether any of them are sufficiently effective against fungi, during a long enough period, and at the same time sufficiently safe to plants and low in cost, to be altogether satisfactory in more than a limited way. Thus, according to Newhall (69)[1], the cost of soil sterilization by formaldehyde is more than $400 per acre. The search for better, safer, and less expensive soil fungicides continues and this bulletin, which includes also some reference to the work of earlier investigators, is a summary of the results of some of the writer's investigations in this field.

Damping-off of seedlings may be caused by species of at least eight genera of fungi (38), but those most common here and the only ones involved in this work are *Rhizoctonia solani* Kühn and species of Pythium. They were isolated from infected seedlings and several strains of them, in culture, were also obtained from other investigators[2]. Although at least two species of Pythium were used, no distinction is made between them, for a control measure effective against one was equally so against another. The strain of *Rhizoctonia solani* used most often was isolated from thyme, the mats of which are often severely injured by this fungus in rainy summers.

Soil was autoclaved several days before inoculation, and the inoculum, the fungus in culture, was well worked into the soil three or four days before it was used. It many cases naturally contaminated soil was also used, in a supplementary way, for the artificial inoculation of an autoclaved soil may mean an unreasonably drastic test of soil fungicides. Fungi were not reisolated from inoculated soil, but they were isolated from damped-off seedlings in such soil.

Seeds (or, in a few cases, cuttings) of the species of ornamental plants listed in the appendix were used. These species are referred to in the text in more abbreviated ways. Use was also made of a number of vegetables—beet, cress (*Lepidium sativum* L.), cucumber, pepper, etc.

Frequent reference is here made to the effect of soil treatments on growth, and the evidence supports the conclusion of Delafon (27) that a soil disinfectant which is good for use with some species of plants may not be at all good with some others. The measure of growth was green weight of seedlings. The most common evidence of stimulation observed was when Rhizoctonia interfered with growth of seedlings in untreated soil, without killing them. Clayton (20) also noticed that plants grew more rapidly in soil which had been freed of Rhizoctonia by formaldehyde, and the writer is of the opinion that much of the so-called stimulatory effect of formaldehyde and other soil disinfectants is thus explainable. This would be less true, however, when only Pythium was involved, for it is more likely to kill quickly than merely to retard the growth of seedlings.

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[1] Reference is made by number to "Literature Cited".

[2] G. P. Clinton, Annie P. Gravatt, C. E. F. Guterman, L. W. R. Jackson, and George L. Peltier.

Seedlings were usually weighed at that age and stage of development at which they are ordinarily transplanted for the first time. What the effects might have been had plants been allowed to grow until flowering, was not determined.

"Damping-off" means post-emergence damping-off unless otherwise indicated, in which case the reference is to the killing of seeds or of seedlings before they had emerged from the soil, and this is more commonly discussed in connection with the effect of treatment on germination. Such effects, provided of course that germination is uninjured by the treatment, are less important, however, than are numbers which germinate and live; in other words, final stands. Final stands are a measure of protection against both pre-emergence and post-emergence damping-off, for approximately the same number of seeds of a given species was used with each treatment in any one experiment.

MEDIA FOR SEEDAGE AND THEIR RELATION TO DAMPING-OFF

As has been well demonstrated by Dunlap (31), there is little or no damping-off of seedlings in washed sand. To provide the necessary plant food, he added to the sand, before seeding, about 2.8 gm. potassium nitrate in 142 cc. water per square foot (1 ounce in 3 pints water for 10 square feet). He found that some species grew better in a mixture of sand and peat moss than in sand.

Some use was made of Dunlap's method, comparing soil, washed sand, sand and sphagnum, and sand and peat moss (about half and half by volume in both cases). Five different sands were used. The media were 3 to 4 inches deep in flats with narrow seams in the bottom. Sands always received potassium nitrate, before seeding, at the rate of 2.8 or 3.0 gm. in 140 or 150 cc. water per square foot.

It was soon evident that sand–sphagnum and sand–peat moss need the nutrient about as much as does sand, for the addition of potassium nitrate increased the weights of plants as follows:

	Percentage Increase due to Fertilizer	
	In Sand–peat	In Sand–sphagnum
Calendula	14	11
Cress	55	50
Beet	59	38

In all later experiments, therefore, potassium nitrate was applied to these media as well as to sand. Soil, of course, received no nutrient.

Results are summarized in Tables 1 and 2, both of which include the means of several experiments. There was little or no damping-off in sand. There was a little more damping-off in sand–sphagnum and in sand–peat moss than in sand, but much less than in soil.

Damping-off was as completely prevented and final stands were as much improved by the use of washed sand as a medium for seedage as by the disinfection of soil with formaldehyde.

TABLE 1.—DAMPING-OFF AND FINAL STANDS IN DIFFERENT MEDIA

Media	Percentages which Damped-off		Relative Numbers of Plants which Lived				
	Beet	Cress	*Viola cornuta*	Marigold	Beet	Cress	Lettuce
Soil.	45	32	100	100	100	100	100
Sand.	0	1	168	172	266	287	528
Sand-sphagnum.	2	3	205	197	219	337	523
Sand-peat moss. .	3	6	159	197	198	249	478

Although washing with hot water frees sand from fungi, it does not prevent their growth if they are reintroduced. In one experiment in which where was no damping-off in washed sand, damping-off was severe when this same sand was inoculated with Pythium. In this connection it is of interest to note that, in the experiments of Abdel-Salam (3), Pythium caused severe damping-off in inoculated sand; but Rhizoctonia caused only 2 percent damping-off in inoculated sand, although it caused 74 percent damping-off in loam. It would seem that washed sands which later become contaminated with Pythium may be more dangerous to seedlings than washed sands contaminated with Rhizoctonia. This defect of washed sand is, of course, not unique with it, for disinfected soil may also become recontaminated with fungi.

As has been shown by Dunlap, the same sand may be used repeatedly if it is well washed with hot water before each seeding. When this practice was followed with sand–sphagnum or sand–peat moss in these experiments, however, there was a little more damping-off than in sand so treated, indicating that washing these media may not free them so completely of fungi as does the washing of sand.

As may be seen by reference to Table 2, none of the species grew so well in sand as in soil. This was true of beet and cress in five different sands, and also of Zinnia, English daisy, and ten-weeks stock in the only sand in which they were seeded. Growth was better in sand than in soil in a few instances, but only when Rhizoctonia, without actually killing the seedlings, seriously interfered with their growth in soil.

TABLE 2.—AVERAGE GREEN WEIGHT PER PLANT IN DIFFERENT MEDIA

(Weights expressed as relative numbers.)

Media	Calendula	Canterbury bells	Marigold	Salpiglossis	*Viola cornuta*	Beet	Cress	Lettuce	Spinach
Soil.	100	100	100	100	100	100	100	100	100
Sand B.	—	—	—	—	56	63	76	—	—
Sand H.	—	—	—	—	100	68	74	—	—
Sand P.	—	—	—	—	78	43	48	—	—
Sand N.	—	—	—	—	70	67	49	—	—
Sand S.	64	34	68	50	82	48	80	78	44
Sand S and sphagnum. . .	121	100	—	—	125	91	129	123	69
Sand S and peat moss. . .	88	100	—	—	106	105	112	112	53

Sands had pH values of 5.8 to 6.1 and water-holding capacities of 24 to 27 percent. They differed more in degree of fineness, and the poorest growth was most often in the finest sand. This is in agreement with observations of Dunlap; and Biekart and Connors (10) preferred a medium-coarse to a finer sand for the culture of carnations in sand.

Growth of seedlings of all species was better in sand–sphagnum and sand–peat moss than in sand alone (with usually a little more benefit from the sphagnum), probably because moisture and nutrients were retained better in these media than in sand. Growth was usually as good in sand–sphagnum and sand–peat moss as in soil, and often better. Peat moss increased the water-holding capacity of the sand and lowered its pH value more than did the sphagnum.

It is evident from the above that sand culture of seedlings controls damping-off, but it is perhaps no more convenient to wash sand and apply nutrients once (or more than once, as Dunlap suggests) than it is to disinfect soil chemically. The principal defect of sands—at least of some sands—is that growth of seedlings may be too slow unless nutrient is applied more than once. Seedlings of tuberous-rooted begonias, Ramondia, *Primula denticulata* and other species grew too slowly in sand to be of a size easy to transplant to better soil when they should have been. There seems to be ample justification for the English horticultural writer (1) who considers sand an ideal medium for germination except for the fact that it requires such vigilant watering (which may mean washing out of nutrient) that it may be necessary to add peat moss to the sand to retain moisture.

Sphagnum was found no less useful. The sand used in such a mixture should be washed with hot water, and the mixture of sand with peat moss or sphagnum needs nutrient about as much as does sand alone.

The medium used in the experiments with soil fungicides was a sandy soil made by mixing a sifted compost of sods and manure with sand, half and half by volume. Soils used for seedage of most species ought to be sandy rather than heavier because of the greater risk of the latter's caking and remaining excessively wet too long if overwatered. It is not to be supposed, however, that the proportion of sand in the soil will have much effect on the severity of damping-off; and in these experiments, as in those of Gratz (39) and Abdel-Salam (3), damping-off caused by Rhizoctonia was severe in a mixture (half and half) of loam and sand. This was true also when such a soil was inoculated with Pythium.

There are soils in the trade which have already been sterilized by the firms supplying them, and, unless they later become contaminated, there is little or no damping-off in them. To lessen the cost of using such soil, it was mixed with washed sand up to half and half. No increase in damping-off resulted, and seedlings grew well without the addition of nutrient up to the stage at which they are commonly transplanted.

SOIL REACTION AND DAMPING-OFF

Certain plant diseases are known to be at least partly controllable by adjusting soil reaction. It is, therefore, of interest to learn to what extent such methods might be expected to be effective in the case of damping-off.

Although investigators are not in complete agreement, it appears from the work of Anderson (6), Jackson (52), and Jones (55) that species of Pythium may cause severe damping-off in soils having pH values of 4.5 or 5.0 to 6.5 or 7.0 and that they may cause some damping-off even in soils with pH values of less than 4.0. That being the case, a soil which is acid enough to inhibit Pythium as a pathogen will probably be too acid for many species of plants.

Going to the other extreme, high pH values, it should be noted that lime as applied to soil by Johnson (54) did not protect seedlings against infection by Pythium. Similar results were obtained here with seedlings of Delphinium and several species of Dianthus when hydrated lime, up to 2 tons per acre, was applied to soil (inoculated with Pythium) which had an initial pH value of 5.0.

Buchholtz (15) was able to reduce the severity of damping-off by a heavy application of lime, it is true, but his soil had an initial pH value of 6.2, and it is reasonable to assume that this may have modified the effect of liming. In a soil with an initial pH of 4.5, an application of lime which changes the pH value to 6.0 might be expected to make damping-off caused by Pythium not less but more severe.

Turning now to Rhizoctonia, it has been established by several investigators (93, 39, 52, 63) that this fungus can grow, at least in culture in artificial media, at pH values ranging from a minimum of pH 2.0 to 3.0 to a maximum of pH 9.0 to 10.0, with the optimum at about pH 6.0 or 7.0. This is a wider range and a higher optimum than that reported by others for Pythium. It does not appear that damping-off caused by Rhizoctonia would be at all readily or practically controllable by the adjustment of soil reaction. Peltier (73) observed that it grew equally well in acid and alkaline soils; Gloyer and Glasgow (38) found it growing well in soil with a pH value of about 7.4; and in experiments of Jackson (52), there was some damping-off until pH values were lowered to 2.5, although the disease was more severe at or near neutrality.

These relations are further mentioned in connection with the use of certain chemicals, especially sulfur, aluminum sulfate, and calcium salts.

SOIL MOISTURE AND DAMPING-OFF

Soil used in seedage is often watered unnecessarily heavily, as a result of which, especially if the soil is inclined to heaviness, it so shrinks, bakes, and cakes as to interfere with germination about as much as fungi do.

Chemical treatments mentioned below were applied to soils which were moderately dry. Soils were watered immediately after seeding. Water was usually applied through papers laid on the soil, so that seeds would be neither washed out nor buried. These papers were left on until seedlings began to emerge. This helps to prevent a too prompt recontamination of the soil, as by dirt blowing upon it, but is unnecessary as far as holding fungicides in the soil is concerned.

Damping-off fungi are sometimes present in water, in which case they may be destroyed by boiling, and some investigators (71, 5) have done that before watering sterilized soil. This was unnecessary with the water used in these experiments, however; for, in sterilized soil, there was as little damping-off of seedlings watered with tap water as of those to which only boiled water was applied.

It has been suggested that damping-off may be at least partly controlled by less heavy or less frequent waterings and by more ventilation, but the indications are that this would be neither easy nor safe. Abdel-Salam (3) concluded from his experiments that a high degree of dryness of the air does not stop the spread of the disease once it has appeared. Alexander and his associates (5) came to the similar conclusion that damping-off caused by Pythium and Rhizoctonia cannot really be controlled in practice by regulating soil moisture; and Gratz (39) found that Rhizoctonia infected plants at any soil-moisture content favorable to their growth. Abdel-Salam had similar results, a strain of Rhizoctonia causing as severe damping-off in relatively dry as in much moister soils. It would appear, therefore, that a soil too dry for damping-off is probably too dry also for germination and good growth. This may be especially true with small seeds, usually sown on the soil surface, for they cannot become dry after germination has begun without some likelihood of injury.

Very small seeds are best watered from below, by the partial immersion of pots in water, for there is then less danger of seeds and seedlings being washed out or buried. Bewley (9) and Gratz concluded that this is also less favorable to damping-off caused by Rhizoctonia than is watering from above. Neither of them asserted that the disease is thus entirely preventable, however; and in the writer's experiments with Pythium, there was about as much damping-off of Nicotiana and Canterbury bells when they were watered from below as when they were watered from above through papers. Soil watered from below may receive too much water at one time and, therefore, remain wet too long unless well and promptly drained. This is more likely to happen with soil of high water-holding capacity or one which contains much peat moss, but there is not much risk in the case of a sandy soil.

TEMPERATURE AND DAMPING-OFF

Earlier investigators (39, 3, 46, 89, 75) have found that Rhizoctonia may infect seedlings and cause damping-off at temperatures from as low as 45° to 48° F. (7° to 9° C.) to as high as 86° to 95° F. (30° to 35° C.), with the optimum temperature for infection variously identified as between 59° and 86° F. (15° to 30° C.).

It has been suggested (54, 9) that temperatures be lowered to help protect seedlings against Rhizoctonia but, on the basis of the figures presented above, the temperatures might have to be lowered to below 60° F. before damping-off could be expected to be checked, and Bewley (9) indicates that there may be no decrease in the disease causeo by this fungus until temperatures have been brought down to below 54° F., which is too low for many species of plants.

Cardinal temperatures for damping-off caused by Pythium have been reported by other investigators as follows:

Minimum: Below 59° F. (5), below 55° F. (46), or 46° F. (3)
Optimum: 86° F. (3), 86° to 68° F. (46), or 75° to 64° F. (5)
Maximum: 95° F. (3), above 86° F. (80), or 86° F. (46)

It appears, therefore, that both Pythium and Rhizoctonia may cause damping-off at temperatures from maxima of 95° to 86° F. (35° to 30° C.) down to minima of 48° to 46° F. (9° to 8° C.), with the optimum for Pythium between 64° and 86° F. (18° to 30° C.) and the optimum for Rhizoctonia between 59° and 86° F. (15° to 30° C.).

It has been suggested (54) that, in an effort to control Pythium, temperatures be lowered to below 70°F., and the results of others, summarized above, do indicate that less infection by Pythium may be expected at temperatures below about 66° F. There may, however, be some infection of seedlings bv Pythium at temperatures as low as 46° F., and the writer has found no published record of complete control of damping-off caused by Pythium by temperature regulation without some adverse effect on germination of seeds or growth of seedlings of some species.

SOIL FUNGICIDES AND DAMPING-OFF

It appears from the foregoing discussion that damping-off is not altogether controllable by the adjustment of the environment. It is, of course, controllable by ridding the soil of fungi, as by the use of various chemicals, although there is need of fungicides which will prevent the recontamination of soils for a longer time than do the commonly used volatile chemicals. Steam is subject to the same criticism, and Anderson (6) concluded that Pythium rapidly reinfests soil thus sterilized, the fungus growing up, in tobacco beds, from unsterilized soil below. He suggested the use of formaldehyde instead of steam, but there is no evidence that its fungicidal effect is much less fleeting and it has been noted by Thomas (85) and by others that formaldehyde treatment of soil does not for long prevent the reintroduction of pathogenic fungi.

This is really no great drawback when only damping-off or early damping-off is to be combated but may be serious with seeds which are slow to germinate or seedlings of species which remain susceptible to infection by soil fungi for a long time. It is true that the susceptibility of most species to damping-off, especially to that caused by Pythium, usually decreases fairly rapidly as plants grow older; but damping-off fungi may injure plants in other ways, and Gratz (39) found that Rhizoctonia may infect seedlings of cabbage until they are more than four months old.

Once the pathogenic fungi have been introduced into soil which was (steam) sterilized some time before, they may cause even more damping-off than in soil not sterilized at all. This was the conclusion of Hartley (43) and of Abdel-Salam (3) with reference to Pythium and Rhizoctonia respectively. Horsfall (48), too, observed that damping-off may be worse in reinfested soil than it was before steaming, and Abdel-Salam made a similar observation in connection with the use of formaldehyde.

It is evident, then, that such treatments are more effective in getting fungi out of soil than in keeping them out, and just how soon sterilized soil may be reinfested is a point of some interest. Pythium grew in soil inoculated by Nolla (71) one week after treatment with formaldehyde, and he applied it twice as heavily as is usually recommended. This indicates that soils so disinfected may become recontaminated with fungi (although, of course, they often do not) by the time seeds are planted, especially if, on the grounds of safety, there is some delay between disinfection of soil and seeding.

We may now, on the basis of the above discussion, consider in some detail the use of a number of chemicals, for more needs to be learned about better methods of using old soil disinfectants and about other chemicals which may have more nearly ideal qualities as soil disinfectants.

Formaldehyde

Formaldehyde has been applied to soil in many different ways. Table 3 includes mention of several representative methods, the number of cubic centimeters of commercial formaldehyde[3] and of water applied per square foot, and results in control of damping-off.

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[3] 37 percent by weight, 40 percent by volume.

TABLE 3.—RESULTS OF OTHER INVESTIGATORS WITH FORMALDEHYDE AS A SOIL DISINFECTANT

Literature Citation	Dilution and Application per Square Foot	Number of cc. per Square Foot		Resulting Control of Damping-off
		Commercial Formaldehyde	Water	
Johnson (54)	1:50, 2 quarts	37.8	1855	Prevented infection by Pythium and Rhizoctonia
Clayton (20)	1:50, applied to soil saturation			Prevented infection by Rhizoctonia
Johnson (54)	1:75, 2 quarts	25.0	1868	Did not prevent infection by Pythium and Rhizoctonia for more than 15 days
Brien and Chamberlain (13)	1.0 percent solution, 1.33 quarts	13.0	1246	Prevented infection by Pythium and Rhizoctonia
Weindling and Fawcett (95)	6.0 percent *dust*, 3 ounces	13.0	0	Prevented infection by Rhizoctonia
Brien and Chamberlain (13)	0.83 percent solution, 1.33 quarts	10.5	1249	Did not prevent infection by Rhizoctonia, but sometimes controlled Pythium
Guterman and Massey (40)	Applied 12 to 24 hours before seeding. Soil well watered after seeding	7.1	39	Controlled damping-off as well as formaldehyde dust
Wilson and Tilford (100)	6.0 percent *dust*, 1.5 ounces—the common recommendation for dust	6.37	0	Killed Pythium: also the mycelium but not the sclerotia of Rhizoctonia
Weindling and Fawcett (95)	6.0 percent *dust*, 1.5 ounces	6.37	0	Failed to prevent infection of citrus seedlings by Rhizoctonia
Guterman and Massey (40)	Applied immediately before seeding. Soil well watered after seeding	5.0–3.3	27–18	Controlled damping-off as well as formaldehyde dust

Acetic acid is sometimes less effective against Rhizoctonia than against Pythium, and there are indications that formaldehyde, too, may be less effective in preventing damping-off caused by Rhizoctonia than that which is caused by Pythium. Thus Wilson and Tilford (100) observed that the formaldehyde dust treatment which kills Pythium (and certain other fungi) in soil also kills the mycelium, but not the sclerotia, of Rhizoctonia; and Weindling and Fawcett (95) concluded that it may be necessary to use 3 ounces of formaldehyde dust per square foot (instead of 1.5 ounces as commonly recommended) to prevent infection of citrus seedlings by Rhizoctonia. Brien and Chamberlain (13) also found that an application of formaldehyde which was at least partly effective against Pythium was completely ineffective against Rhizoctonia. Hartley (43), too, noted that formaldehyde does not always rid soil of Rhizoctonia, and Peltier (73) was not altogether successful in protecting carnations against this fungus with formaldehyde.

An application of this or other chemical may, of course, be too light to kill either fungus; but, as may be seen from Table 3, damping-off has been satisfactorily prevented by as little as 7, 5, or even 3 cc. formaldehyde per square foot. These are very small applications, compared with the 37 cc. per square foot which results when 2 quarts of the 1:50 dilution of formaldehyde, long a standard recommendation, is applied. That method is going out of favor, principally because of the 10 to 14 days' delay necessary between soil treatment and seeding. Yet an application of two quarts per square foot of a slightly weaker solution, 1:75, equal to about 25 cc. formaldehyde per square foot, was found by Johnson (54) to be ineffective against both Pythium and Rhizoctonia after 15 days. It may be that some of the smaller applications (such as the 6.37 cc. of formaldehyde in 1.5 ounces of a 6 percent dust) would not be effective for any longer; but they are generally used with satisfactory results (100, 40).

These new methods differ from the old, and this may be important, in that less water as well as less formaldehyde is applied per square foot—as much as 1855 cc. by the old method, and as little as 30 cc. or none at all by the new. The explanation is probably to be found in the conclusion of Yu (102) that the fungicidal effects of formaldehyde (and of acetic acid) are greater if soil to which they are applied is not very wet. It may be necessary to add more water to soil at time of seeding, but the indications are that less of the fungicide is needed if not too much water is applied with the treatment, especially if the chemical is mixed with the soil. Then too, formaldehyde has been found to escape more rapidly from a drier than from a wetter soil (100), which is one explanation of why the time interval before seeding may safely be shorter.

But the less dilute the chemical when applied to soil, the greater may be the need of later watering, at time of seeding, to prevent injury. This is the common recommendation when formaldehyde dust is used, and Guterman and Massey (40) found it necessary to water thoroughly, after seeding, soil which had been treated with formaldehyde (about 7 cc. per square foot in about 40 cc. of water) 24 hours previously. The writer has found their method effective against damping-off and safe with the seeds used, but there was injury to cuttings of an herbaceous plant, *Nepeta Mussini*, inserted 24 hours after this treatment of a sandy soil.

Haensler (41) was able to control damping-off by formaldehyde 1:300, applied at the rate of 0.75 quart per square foot immediately after seeding. This is a very light application of formaldehyde indeed, only about 2.3 cc. per square foot; but, as used by the writer, it markedly improved germination and prevented most early damping-off. It was not injurious to tomato, eggplant, pepper, or lettuce. It did injure cress, crucifers being more subject to injury by formaldehyde, as Haensler observed, than are some other plants. Such use of fungicides, after rather than before seeding, is further discussed below.

Acetic Acid, Acetic Acid Dusts, and Vinegar

The soil in these and the following experiments was 3 to 4 inches deep in flats or earthen pans. Chemicals were applied on the basis of the number of grams or cubic centimeters per square foot of soil surface.[4] Except as otherwise noted, chemicals were worked into the soil before seeding.

Acetic acid 1.0 to 1.2 percent (2 quarts per square foot, 1 or 2 weeks before seeding) was found (28, 29) to be a safe and effective soil disinfectant. As has been pointed out by Newhall, Chupp, and Guterman (70), it is less unpleasant to breathe then formaldehyde and, in well-ventilated greenhouses, it can be used with less injury near plants. In the work of Yu (102), acetic acid 1.5 percent was also less injurious to germination of cucumber than was formaldehyde 1:50, with both applied 9 days or more before seeding. Since its merits were first pointed out, other investigators have used it with good results. (See Table 4.)

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[4] One gm. per square foot is 96 pounds per acre, and 20.8 gm. per square foot is 1 ton per acre.

It is of interest to note, however, that Christoff (18), using a 1.0 percent solution, controlled damping-off of conifers more completely in an acid than in a highly alkaline soil; but with the latter, the writer has had no experience.

TABLE 4.—RESULTS OF OTHER INVESTIGATORS WITH ACETIC ACID AS A SOIL DISINFECTANT

Literature Citation	Fungi Involved	Dilution, Application per Square Foot, and Days before Seeding	Results
Flachs (36)	Sclerotinia	1.5 percent, 1 quart	Damping-off of lettuce well controlled
Gill (37)	Pythium and Rhizoctonia	1.0 percent, 1 quart, 7 to 10 days	Control of geranium cutting rots compared favorably with that by formaldehyde 1:50
Brien and Chamberlain (13)	Pythium and Rhizoctonia	1.0 percent, 1.3 quarts, 14 days	Damping-off of tomato seedlings well controlled
Christoff (18)	Pythium and Rhizoctonia	1.0 to 1.2 percent, 1 quart, 7 to 10 days	Damping-off of seedling conifers well controlled
Yu (102)	Pythium	1.5 or 2.0 percent, 2 quarts, 9 to 13 days	Damping-off of cucumber well controlled
Sherbakoff (80)	Septoria	1.0 percent	Good control of tomato leaf spot, when supplemented by spray of Bordeaux mixture
Anderson (6)	Pythium	1.0 percent, 2 quarts, 7 days or more	Damping-off of tobacco well controlled

Acetic acid 1.0 or 1.5 percent (approximately) may be made by diluting glacial acetic acid 1.0 or 1.5 gallons to total 100 gallons. Two quarts of these dilutions per square foot cannot be applied less than one week before seeding without injury to some species; for example, foxglove, sweet pea, and beet. Cucumber is more tolerant. A 1.5 percent solution applied 10 days before seeding was harmless to these species and to *Veronica repens*, *Cheiranthus Allionii*, and *Lilium philippinense*. All damping-off was prevented, germination was improved, and, because of infection by Rhizoctonia in checks, growth was improved.

The effect of acetic acid on the pH value of treated soil does not usually last more than two or three weeks.

A principal objection to acetic acid, as to formaldehyde, thus used is the delay of a week or two before seeding and this, in the case of formaldehyde, has been overcome by the use of the dust. Guterman and Massey (40) were equally successful in using a small quantity of formaldehyde (about 7 cc. per square foot in 5 times that volume of water) 12 to 24 hours before seeding, the soil being then well watered.

Acetic acid 80 percent, 8 cc. per square foot, thus diluted and mixed with soil did not injure Torenia, Verbena, Calendula, cabbage, and pepper and it did improve their germination without, however, preventing all damping-off.

Acetic acid 80 percent, 8 cc. per square foot, and also formaldehyde 7cc., each diluted with 5 times that volume of water, were also applied to (but, of course, not mixed with) soil immediately after seeding. Thus used they were injurious to Felicia, Linanthus, *Mathiola bicornis*, as well as the species mentioned above, which were uninjured when these quantities of acetic acid or of formaldehyde were mixed with soil before seeding. Pepper, seeds of which germinate slowly, was least injured by these treatments applied after seeding.

Acetic acid dusts, on the use of which the writer has briefly reported (30), were made by mixing the acid with powdered wood charcoal. Some of the best, containing 23 or 24 percent acetic acid, consisted of 1 pint of 80 percent acetic acid with 2.5 or 2.75 pounds of charcoal, or 1 pint of glacial acetic acid with 3.5 pounds of charcoal. These were stored in practically airtight containers and worked into the soil shortly before seeding, at the rate of 1.5 ounces per square foot. Soils were well watered immediately following seeding.

In soils inoculated with Pythium and Rhizoctonia, germination was improved and the severity of damping-off was lessened by a 15 percent dust, but the control of damping-off was increasingly good when dusts contained 18 to 24 percent acetic acid, with best control by the 23 and 24 percent dusts.

The relative numbers of plants which lived are recorded in Table 5, which includes the means for several experiments. A 23 percent acetic acid dust also improved germination of Browallia, Cerastium, English daisy, columbine and lupine.

TABLE 5.—EFFECT OF ACETIC ACID DUSTS ON FINAL STANDS

Percentage of Acetic Acid in Each Dust	Relative Number of Plants which Lived						
	China Aster	Dahlia	Delphinium	Sweet Pea	Zinnia	Beet	Cress
Check.......	100	100	100	100	100	100	100
19...........	—	383	—	—	—	210	722
22...........	—	380	—	193	196	—	1283
23...........	417	—	—	275	—	554	4056
24...........	573	—	221	282	218	535	4020

The effect of a 23 percent dust in improving stands is also shown in Figure 1. This dust, applied to soil immediately or within 24 hours before seeding, was harmless to the species named in Table 5 and above, and also to rocket, Laburnum, arbor-vitae, onion, *Rhododendron calendulaceum*, *R. catawbiense*, *R. carolinianum*, and *R. Schlippenbachii*. Perhaps it would not be harmless to all species, for Alexander, Young, and Kiger (5) injured tomato seeds with a 20 percent acetic acid dust, although their carrier was not charcoal but diatomaceous earth and kaolin.

These acetic acid dusts, as made and used by the writer, were, however, unsafe with cuttings, for even a 17 percent dust, applied to a mixture of sand and peat moss 24 hours before their insertion, injured Ilex, Berberis, *Lonicera pileata*, Euonymus, Calluna, Chamaecyparis, and Erica.

Vinegar as usually sold contains 4 to 5 percent of acetic acid and it has occasionally been recommended, as by Stafford (82), for the control of damping-off. It is doubtful, however, whether there is much experimental evidence on which to base such recommendations and they usually call for much less vinegar than the writer (30) has found necessary.

Four brands of cider vinegar were used in this work, and the results did not differ significantly one from the other. Undiluted vinegar was worked into the soil immediately before seeding, except as otherwise indicated. Some of these soils had been inoculated with Pythium or Rhizoctonia and others were naturally infested. The soils were well watered immediately after seeding. Results are recorded in Table 6 in terms of percentages which damped-off and relative numbers of plants which lived.

TABLE 6.—EFFECT OF VINEGAR ON DAMPING-OFF AND ON FINAL STANDS

Vinegar cc. per Square Foot	Arbor-vitae	China Aster	*Centaurea Cyanus*	*Cheiranthus Allionii*	Dimorphotheca	*Dianthus arenarius*	Delphinium	Lupine	Mesembryanthemum	Ranunculus	Verbena	Zinnia	Cress	Beet	Lettuce	Spinach
Percentages which Damped-off																
Check ..	21		22	49									53	36	25	27
140...	16		—	—									20	—	—	—
175...	5		—	—									16	14	—	—
195...	—		—	8									13	9	7	—
215...	—		3	2									13	4	5	—
235...	—		—	—									8	2	0	6
250...	—		0	0									1	1	0	2
Relative Numbers of Plants Which Lived																
Check ..		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
140...		—	—	—	—	—	—	—	—	117	—	—	312	—	—	—
175...		—	—	—	121	163	—	—	—	233	—	—	393	233	—	—
195...		—	167	—	—	—	—	—	133	—	—	—	280	307	—	—
215...		—	204	162	—	265	129	137	142	—	131	—	538	300	316	—
235...		600	229	—	—	—	129	—	—	—	—	196	637	318	343	—
250 ..		623	225	170	—	258	143	146	167	—	145	189	834	509	343	197

Damping-off caused by Pythium and Rhizoctonia was usually well controlled by 215 cc. vinegar per square foot, with better control by 235 cc. (about one-half pint). Germination of most species, especially those like cress and beet which are very susceptible to damping-off, was usually much improved also. Beneficial effects on stands are illustrated in Figure 1. Vinegar in too small quantities to prevent damping-off, down to 140 cc. per square foot, often improved germination.

As may be seen from the following tabulation, the quantity of vinegar which can be safely used immediately before seeding is not the same for all species.

As compared with check plants infected by Rhizoctonia, growth was often improved by 200 to 240 cc. vinegar.

At present it does not seem wise to suggest the use of more than 237 cc. (one-half pint) of vinegar per square foot, to be worked into the soil immediately before seeding; and lighter applications are sometimes sufficient in soils not too heavily infested with fungi. Homemade vinegar may, according to Wyant (101), have a higher content of acetic acid than the vinegar which is commonly sold, and must, therefore, be used with extra caution unless it has first been diluted to about 4 percent acidity.

Vinegar per Square Foot	Species Injured	Species not Injured
260 cc.	Androsace Beet	China aster Delphinium Celery
255 cc.	Candytuft	
250 cc.	Cress	*Alyssum saxatile* Arenaria Silene Zinnia Cabbage
245 cc.		Arabis Beet Cucumber Spinach
235 cc.		Androsace Rocket candytuft Calendula Sedum Morning-glory Lettuce Pepper Tobacco Tomato
230 cc.		*Centaurea Cyanus* Lupine Cress
200 cc.		*Mathiola bicornis* Pyrethrum Ranunculus Arbor-vitae

We come now to the use of vinegar applied to the surface of soil *after* seeding. It cannot then be worked into the soil and is, therefore, more concentrated near the surface of the soil and near the seeds. Vinegar, with or without dilution, was thus applied in several experiments and its effects on germination are summarized in Table 7.

Quantities of vinegar which were entirely safe if worked into the soil before seeding were injurious to seeds of some of the same species if applied to the surface of the soil immediately after seeding. The important point seems to be not so much *when* as *how* vinegar is applied, for there was often no more than 10 minutes' difference between applications made after seeding and those made before.

Vinegar applied after seeding was least injurious in the case of seeds which germinate relatively slowly, such as Opuntia or even pepper; and it was most injurious in the case of seeds which germinate relatively promptly, before enough acetic acid has escaped from the soil, such as cabbage and Calendula. Seeds and seedlings of Opuntia, which are prone to damp-off, were well and safely protected by 237 cc. of vinegar, undiluted, applied to soil after seeding. Such an application may, however, be decidedly unsafe with some other species which germinate more rapidly.

Germination was injured more than was growth. Growth of the species named in Table 7, with the exception of cabbage, was unaffected or improved by 237 cc. of vinegar diluted with an equal volume of water. Growth of cabbage was injured by as little as 189 cc. thus diluted.

Not only vinegar, but also acetic acid (80 percent) 8 cc., and formic acid 3.5 cc. per square foot were found to be considerably more injurious when applied to soil after seeding than before, and, as has already been said, as little as 2.3 cc. formaldehyde applied after seeding is injurious to crucifers.

It is not at all certain that such light applications would be for long effective in preventing fungi from growing up from the soil below, but the method has the advantage of convenience and is now being investigated further.

TABLE 7.—EFFECT ON GERMINATION WHEN VINEGAR WAS APPLIED TO SOIL AFTER SEEDING

Application of Vinegar per Square Foot	Germination Injured	Germination Unaffected	Germination Improved
237 cc. undiluted	Agapanthus *Antirrhinum maurandioides*	Calla Lachenalia *Mentha Requienii*	*Opuntia* sp. *O. humifusa* *O. vulgaris*
237 cc. diluted with an equal volume of water	Calendula Cabbage		Pepper Beet Tomato (after a little delay)
220 cc. diluted with water to 3 pints	Felicia Linanthus Cabbage Celery	Pepper	
200 cc. undiluted	Calendula Cabbage	Pepper	
200 cc. diluted with water to 3 pints	Calendula Torenia Verbena Cabbage	Pepper	
189 cc. undiluted	Cabbage		Calendula Beet Pepper
189 cc. diluted with an equal volume of water	Cabbage		Calendula Beet Pepper

In a few cases, soils were watered with diluted vinegar after the emergence of seedlings, and a very little vinegar—too little to prevent damping-off—was then injurious. Twenty cc. per square foot, diluted with whatever water the soil needed and applied whenever water was needed, was harmful to the growth of Ageratum, Thunbergia, cress, and lettuce; and 50 cc., thus applied, was also injurious to beet, pepper, and tomato.

Pyroligneous Acid

This is not a chemical compound, but a mixture of acetic acid and a number of other constituents in water (45). In earlier work (29), the undistilled pyroligneous acid (diluted 4:100, 2 quarts per square foot) prevented most damping-off and was safe to use one day before seeding. This undistilled acid, except as indicated below, had been made by converting hardwoods (birch, beech, and maple) into charcoal and distilling the smoke. It differs from the distilled acid in containing some, or more, wood tar.

The acids were variously diluted, 4:100 meaning 4 parts of the acid with 96 parts of water, and they were, except as indicated below, applied to soil within a few hours before the seeds were sown.

Undistilled pyroligneous acid was more effective in controlling damping-off than was the distilled. Results with each, the means in five experiments, with 2 quarts applied per square foot, are recorded in Table 8. Distilled pyroligneous acid, 6:100, reduced the severity of damping-off, but did not satisfactorily control the disease.

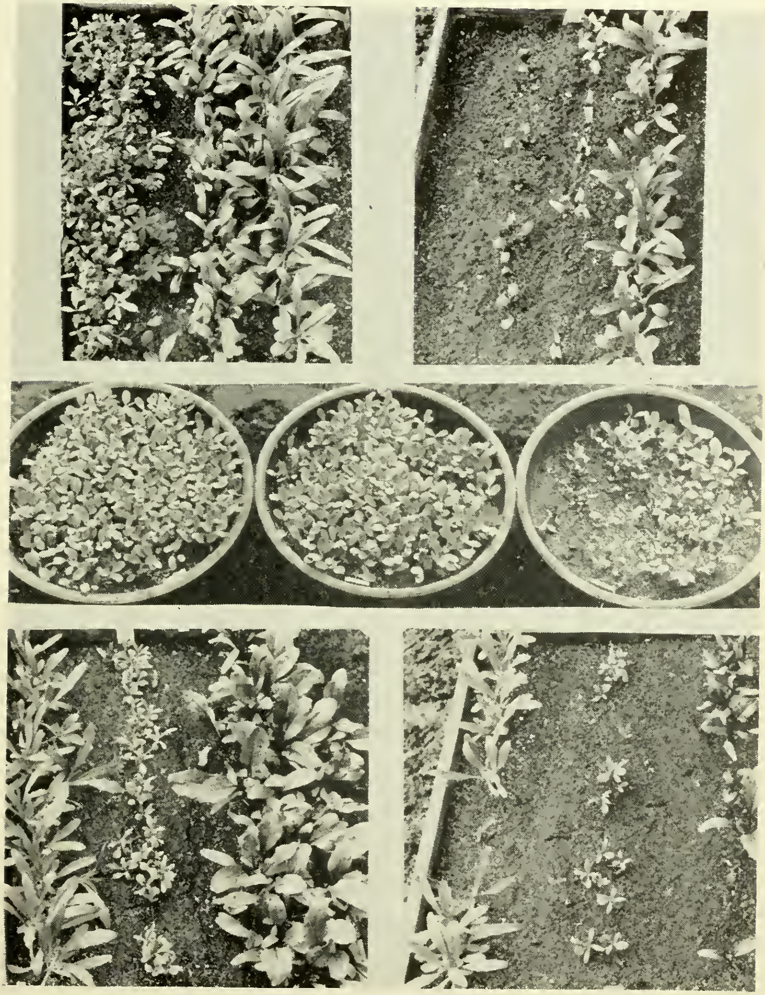

Figure 1. Effect of Acetic Acid Dust and Vinegar on Final Stands.

UPPER: Left--Acetic Acid Dust, 23 percent. Right--Check.
Plants (left to right)--cress, beet, cornflower.
CENTER: Left--Vinegar 237cc. Center--Vinegar 218 cc. Right--Check.
Plants--lettuce.
LOWER: Left--Vinegar 220 cc. Right--Check.
Plants (left to right)--Dimorphotheca, Dianthus arenarius, beet.

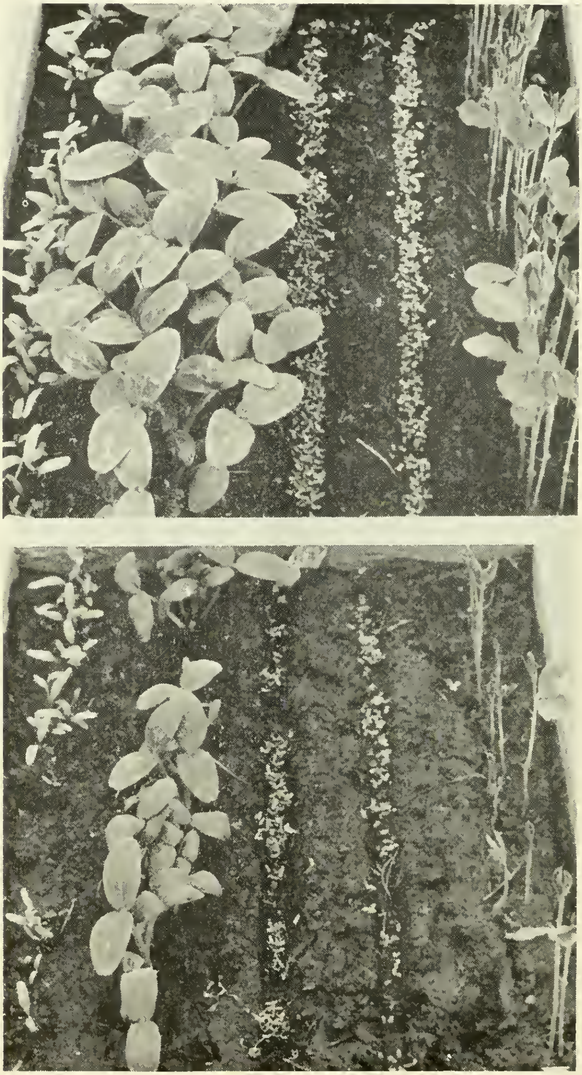

Figure 2. Effect of Pyroligneous Acid on Final Stands.

UPPER: Pyroligneous Acid 5:100.
LOWER: Check.

Plants (left to right)--beet, cucumber, foxglove, Canterbury bell, sweet pea.

Table 8.—Effect of Pyroligneous Acid on Damping-off and on Final Stands

Soil Treatment	Percentages which Damped-off		Relative Numbers of Plants which Lived	
	Beet	Cucumber	Beet	Cucumber
Check	19	53	100	100
Distilled acid				
4:100	19	40	132	100
5:100	6	31	127	127
6:100	8	15	123	136
Check	19	53	100	100
Undistilled acid				
3:100	4	9	210	293
4:100	0	7	217	453
5:100	0	4	198	565

Damping-off was usually well controlled and germination much improved by undistilled pyroligneous acid 5:100. Its effects on germination and on damping-off are shown in Figure 2. The severity of damping-off was also lessened in most cases by a dilution of 4:100, although neither this nor 5:100 was always so effective as acetic acid, and different samples of this pyroligneous acid were not all equally effective. Effects of these treatments on several species are here summarized.

Pyroligneous Acid Undistilled	Species Not Injured	Species Sometimes Injured
5:100	Sweet pea Petunia Mignonette Nicotiana Sweet Alyssum	English daisy Beet Cucumber
4:100	English daisy Marigold Ageratum Sweet William *Viola cornuta* Beet Cucumber	

In later experiments, a pyroligneous acid made from pine wood was applied to soil, without dilution, immediately before seeding. In amounts up to 125 cc., it did not injure beet, cress, and lettuce, and 125 cc. controlled damping-off very satisfactorily. There was considerable benefit also from 100 cc. per square foot when it was diluted to 1 liter and applied after seeding. Its use, both before and after seeding, deserves to be investigated further.

Formic Acid

According to Rideal and Rideal (76), formic acid has a higher antiseptic power than acetic acid, and Uppal (90) found it more toxic to *Phytophthora colocasiae* Rac. than acetic acid.

As used in these experiments, 7 cc. of 90 percent formic acid, diluted to 250 cc. and worked into the soil immediately before seeding, controlled damping-off very well. This effect plus the better germination, as compared with checks, resulted in marked improvements in the final stands:

	Increase in Final Stand Percent
Canterbury bells	100
Beet	442
Cress	377

Thus applied, there was no injury to *Anchusa azurea*, Canterbury bells, *Cheiranthus Allionii*, Galega, beet, and cress.

This quantity and as little as 4 cc. if applied to soil *after* seeding, was injurious to these species and to Felicia, Calendula, Linanthus, and celery. It is, however, a real fungicide, harmless enough to plants if applied to soil before seeding and its use in this way merits further investigation. It must, of course, be handled with care, because of the danger of injury to the skin.

Acetaldehyde

Acetaldehyde is known to have fungicidal properties, and Tomkins and Trout (87) found that it lessened the severity of a Penicillium rot of citrus. As used here, it was less effective against damping-off caused by Pythium and Rhizoctonia, than is formaldehyde; although dilutions of 1:30 to 1:50, applied at the rate of 2 quarts per square foot, resulted in considerable improvement in germination, especially of sweet pea.

It was also less toxic to plants than is formaldehyde, a dilution of 1:30 being harmless to pasque flower, Canterbury bells, sweet pea, Drummond's phlox and cucumber, seeds of which were sown 9 days after soil treatment. Growth of sweet pea in soil inoculated with Rhizoctonia was improved almost 100 percent by a dilution of 1:40 and its use, at least with sweet pea, is deserving of further investigation. On the whole, however, and as compared with formaldehyde, it seemed to lack toxicity to both plants and fungi.

Acetone

Acetone was found by Tomkins (86) to inhibit the growth of some fungi in the way that formaldehyde does; but, like acetaldehyde, it was less effective than formaldehyde in controlling damping-off in experiments conducted here. This was true of a dilution of 1:20 (2 quarts), and it is unlikely that heavier applications could be used safely—immediately before seeding, anyway—for even this application, 3 days before seeding, was slightly toxic to some species.

Ethyl Alcohol

Ethyl alcohol (vapor) is known (86) to retard the growth of fungi, and Roberts and Dunegan (78) found that it entirely prevented the growth of a Sclerotinia.

As used by Christoff (18), a dilution of 1:50 (about 1 quart per square foot) injured the germination of seeds of *Pinus sylvestris* L., but that may have been because he applied it to the soil after seeding rather than before.

Species vary in their tolerance of this as of other chemicals, and sweet pea was uninjured by applications which were toxic to beet and cucumber. Sweet pea was also the species most benefited by alcohol applied to the soil some days before seeding, while the growth of Arabis was not affected. Although damping-off was not altogether satisfactorily controlled by ethyl alcohol, its severity was lessened by 40 to 60 cc. of 95 percent alcohol, applied to soil 8 days before seeding, and the results, especially with sweet pea, were of sufficient interest to warrant its further consideration as a soil fungicide.

Salicylic Acid

This acid and acetic acid were found by Bitting (11) to be more actively fungicidal than are some other acids, and Dunn (32) concluded from his work that salicylic acid may be even more toxic, at least to a species of Sclerotinia, than is acetic acid. Further evidence is to be had from the results of Hermann and Neiger (47) and of Janke and Beran (53), who found that very low concentrations of salicylic acid are toxic to *Tilletia tritici* (Bjerk.) Wint. and to Trichothecium respectively. Little if any practical use seems to have been made of it as a soil disinfectant, however; although, as a crystalline powder, it has the advantage of being readily applied to soil without the necessity of first preparing either a solution or a dust.

Post-emergence damping-off, in soils heavily inoculated with Pythium and Rhizoctonia, was not usually well controlled by less than 6 gm., with better although not always complete control by 8 or 10 gm.; but germination and final stands were usually much improved by 4 to 10 gm. This fact, in the case of several species, is brought out in Table 9.

TABLE 9.—EFFECT OF SALICYLIC ACID ON FINAL STANDS

Salicylic Acid Gm. per Square Foot	Relative Number of Plants which Lived				
	Columbine	Ten-weeks Stock	Beet	Cress	Cucumber
Check	100	100	100	100	100
4	—	110	223	344	—
5	—	185	—	560	272
6	456	185	263	582	287
8	461	200	242	1280	—
10	—	209	—	1283	—

Soil pH values, 2 weeks after seeding, showed no effect from 8 gm. or less—a point to be considered in connection with effects on growth; and it may be noted further that Dunn was inclined to attribute the toxicity of salicylic acid more to the undissociated molecule than to the H-ion.

As applied to soil, immediately before seeding, salicylic acid, up to 10 gm. did not injure the germination of seeds of any species used. Its effects on their growth were as follows:

Salicylic Acid amount	Growth Injured	Growth Not Affected
10 grams	Phlox	Ten-weeks stock
8 grams	Aubrietia Sweet pea Cress	Phlox Beet Cucumber
6 grams		Aubrietia Sweet pea Cress Columbine Rocket
4 grams	*Laburnum alpinum* Foxglove	Arbor-vitae *Rhododendron carolinianum* *R. catawbiense* *R. molle* *R. Schlippenbachii*

These results, while not complete and consistent enough to warrant definite recommendations, were sufficiently encouraging to suggest the value of further experimentation with salicylic acid as a soil fungicide, at least with such species of plants as are relatively tolerant of it.

Tannic Acid

Tannic acid, as used, gave no evidence of being fungicidal, but the growth of foxglove was much improved by 3 to 6 gm. per square foot, even 19 weeks after seeding. Growth of columbine was also improved, although less than was foxglove. These treatments had no effect, however, upon the growth of *Rhododendron carolinianum, R. catawbiense, R. Schlippenbachii,* rocket and sweet pea.

Tannic acid apparently affected these soils physically, improving tilth and making them looser and less sticky, with this effect first noticeable immediately after treatment. This may be related to the response of foxglove, a species which grows well in loose-textured soils, rich in leafmold.

There is an occasional statement in horticultural literature, for example that by Durand (33), to the effect that the acidity of a moderately acid soil may be increased by tannic acid; but it did not appear in this work that such effect as tannic acid may have on plants has much if any relation to soil reaction. When it was applied to soil which had an initial pH value of 6.2, amounts up to 12 gm. did not have any effect on pH value 9 weeks after soil treatment; and 20 gm., as far as it affected soil reaction at all, made soil a little less rather than more acid 3 weeks after soil treatment. According to Laurie and Chadwick (57), earlier investigators have secured similar results, 500 pounds of tannic acid per acre having little or no effect on soil reaction.

Ammonium Hydroxide

As applied to soil by Johnson (54), ammonia did not control damping-off, and Hartley (43) concluded that its effect is too fleeting to protect conifer seedlings.

Ammonium hydroxide, if applied to soil heavily, is, however, an effective soil fungicide and it has been used successfully by Neal, Wester and Gunn (68) to protect cotton against root rot and by Davey and Leach (26, 58) to reduce the extent of infection of sugar beets by Sclerotium. It does not necessarily follow that it would be useful against damping-off, for Neal and Gilbert (67) state that a 4 percent solution should be applied to soil at least six months before planting, and that is certainly too long to wait if only damping-off is being combated.

Ammonium hydroxide (sp. gr. 0.9, a minimum of 27 percent NH_3) diluted with water in the proportions of 1:30 to 1:80 was applied to soil (2 quarts per square foot) 8 to 15 days before seeding. Results with beet and cucumber, means for five experiments with each species, are recorded in Table 10.

TABLE 10.—EFFECT OF AMMONIUM HYDROXIDE ON DAMPING-OFF, FINAL STANDS, AND GROWTH OF SEEDLINGS

Ammonium Hydroxide Dilution	Percentages which damped-off		Relative numbers of plants which lived		Green weights per plant as relative numbers	
	Beet	Cucumber	Beet	Cucumber	Beet	Cucumber
Check	42	41	100	100	100	100
1:80	43	—	216	—	—	—
1:70	39	38	217	150	98	—
1:60	19	31	283	153	120	100
1:50	15	9	249	178	107	129
1:40	5	7	277	196	63	119
1:30	3	0	325	329	40	78

There was practically no damping-off of these or other species with a dilution of 1:30; very little with 1:40; more, although usually not much more, with 1:50; too much, although less than in the check, with 1:60; and no control with lesser concentrations. For the prevention of damping-off caused by species of Pythium and Rhizoctonia, both of which were isolated from damped-off plants, it was necessary to use dilutions of 1:40 to 1:50, which means not less than 9 gm. NH_3 per square foot.

The following treatments, by preventing pre-emergence damping-off, also improved germination unless, because of too great a concentration, there was chemical injury to some species.

Dilution of ammonium hydroxide	Time of application	Germination Improved	Germination Injured
1:40	8 days before seeding	Foxglove Canterbury bells Beet	Sweet pea
1:50 and 1:60	10 or 12 days before seeding	Foxglove Canterbury bells Mignonette Salpiglossis Lupine *Alyssum saxatile*	

Two or three times as many beet and cucumber germinated and lived (see Table 10) with dilutions of 1:50 to 1:30 as in the check.

Growth of all species was injured by a dilution of 1:30 applied to soil 10 to 15 days before seeding, and a dilution of 1:40 was a little injurious to growth of *Alyssum saxatile*, sweet alyssum, sweet pea, and beet, but not to Scabiosa. A dilution of 1:50 was usually harmless to these species and to *Cheiranthus Allionii*; and this and lesser concentrations, often too weak to prevent damping-off, improved the growth (as compared with checks) of Salpiglossis, lupine, Canterbury bells, and cucumber.

Ammonia, as a soil fungicide for the control of damping-off, should have more attention, since it is not only definitely fungicidal but also readily available and, of course, a source of nitrogen. The results may not be quite the same in all soils, however, for Davey and Leach (26) concluded that the fungicidal effect of ammonia is influenced by soil reaction. Dilutions more concentrated than 1:50 will probably be injurious to many species if applied less than 10 days before seeding, but this dilution or 1:60 may well be tried. Weaker solutions may, of course, be used nearer to the time of seeding, but that they will protect against damping-off has yet to be proved.

Ammonium Thiocyanate

Organic thiocyanates are known to be highly toxic to fungi (99), and Andes (7) concluded that ammonium thiocyanate may be used for the disinfection of soil. It is, however, so toxic to plants as to be a good weedicide (44), and Andes found it necessary to wait six weeks before tobacco seeds could be sown safely in soil treated with a 3.0 percent solution (2 quarts per square foot).

The writer used much lighter applications. Two and 3 gm. seemed to have some fertilizer value and greatly improved the growth of sweet alyssum, seeds of which were sown 16 days after soil treatment, but damping-off was not prevented by 7 gm. This amount, or even 5 gm., applied to soil 20 days before seeding, was injurious to Salpiglossis, Petunia, Canterbury bells, foxglove, and heliotrope.

Ammonium thiocyanate may, therefore, be said to remain toxic to plants too long to be a good soil fungicide, since the need is for treatments which may be used at the time of seeding or not long before.

Calcium Cyanamide

Calcium cyanamide, a nitrogenous fertilizer which is known (62, 92, 65, 12) to have some effect as a soil fungicide, was used in several experiments, the results of which are summarized in Table 11. Applications of 6 to 18 gm. were well mixed with soil, naturally infested with Pythium, 10 to 14 days before seeding. Damping-off was not well controlled by 8 gm. or less, but there was good control by 10 or 12 gm. or more.

The exact quantities necessary may, on the basis of the work of Walker and Larson (92) with cabbage club root, possibly be different in different soils; and Boning (12) found that applications too light to prevent all infection by Pythium at least delayed primary infection.

Table 11.—Effect of Calcium Cyanamide on Damping-off and on Final Stands

Calcium Cyanamide Grams per Square Foot	Beet			Cucumber			Calendula	Sweet Pea
	Exp. 1	Exp. 2	Exp. 3	Exp. 1	Exp. 2	Exp. 3		
	Percentages Which Damped-off							
0	50	10	21	25	10	26	15	32
6	51	—	—	22	—	—	4	0
8	5	1	6	25	10	25	3	0
10	0	0	—	0	5	—	2	0
12	5	0	5	0	0	0	0	0
14	0	0	0	0	0	0	0	0
16	3	0	0	0	0	0	1	0
18	2	—	—	0	—	—	0	0
	Relative Number of Plants Which Lived							
0	100	100	100		100	100	100	100
6	200	—	—		—	—	131	227
8	429	126	436		154	322	144	253
10	424	136	—		215	—	123	293
12	485	138	291		142	823	133	346
14	480	120	259		138	800	133	313
16	393	125	264		154	725	141	260
18	521	—	—		—	—	110	249

Germination of seeds was affected by soil treatments, as follows:

Germination Injured

Calcium cyanamide Grams	Time between treatment and seeding	Species
15	11 days	Salpiglossis Mignonette
14	14 days	Scabiosa *Alyssum argenteum*
16	16 days	*Oenothera fruticosa*
	Germination Improved	
8–10	2 weeks	Calendula Sweet alyssum Sweet pea Beet Cucumber
12	2 weeks	Scabiosa
10	2 weeks	*Alyssum argenteum*
6–12	11 days	Foxglove Salpiglossis Canterbury bells Mignonette

Calcium cyanamide was injurious to growth of all of the preceding species, also to *Anchusa myosotidiflora*, when 15 gm. were applied to soil 10 to 14 days before seeding. So applied, 10 gm. were not harmful, except to Calendula; and 12 gm. did not injure Anchusa, *Alyssum argenteum*, sweet pea and cucumber. Six to 10 gm. improved the growth of Anchusa, Alyssum and Scabiosa and might have so affected other species had final readings been taken later, when seedlings were older.

If the necessary delay between soil treatment and seeding is not considered too serious an objection, more use might well be made of calcium cyanamide as a preventive of damping-off. It is not to be recommended, however, in the case of Ericaceous plants or others which prefer an acid soil, for it is known (65) to increase the pH value of soil, 100 pounds of calcium cyanamide having a lime value equal to about 70 pounds of hydrated lime; and in a soil used by the writer an initial pH value of 6.4 was raised to 6.7 by 14 gm. per square foot.

One ounce for 2 to 4 square feet of soil is about 14 to 7 gm. per square foot, and these are the amounts which may be used experimentally, with different species, in different soils and at different lengths of time before seeding. For increased safety, as a consequence of its more rapid decomposition (23), calcium cyanamide should be thoroughly mixed with the soil. The soil should be moist; and the poorer and more sandy it is, the longer should be the interval, according to McCool (65), between soil treatment and seeding.

The time interval necessary between soil treatment and seeding—during which the nitrogen of the cyanamide is changing into the urea and the ammonia forms—will also depend on the species of plant and, unless experience has shown that it may be shorter, should probably be about 2 weeks in the case of the quantities necessary to control damping-off.

Table 12.—Effect of Calcium Hypochlorite on Growth of Seedlings

Calcium Hypochlorite Gm. per Square Foot	Days before Seeding	Species Injured	Species Not Injured
28	21	China aster Physostegia Heliotrope Foxglove	Ten-weeks stock
20	14	China aster Physostegia Heliotrope	Ten-weeks stock
14	7	Physostegia Heliotrope	Ten-weeks stock China aster
12	15	Foxglove Sweet pea Regal lily Snapdragon *Anchusa azurea*	
4	13	*Centaurea macrocephala* Beet Cucumber	Nasturtium Sweet alyssum

Calcium Hypochlorite

Calcium hypochlorite, chlorinated lime, or bleaching powder, often called chloride of lime, has fungicidal properties (14, 91). That used by the writer contained 26 to 30 percent available chlorine and was applied, dry, to soil some days or weeks before seeding.

Germination was not injured so much as was growth and in some cases was even improved by the treatments named in Table 12. The severity of damping-off was in some cases lessened also, but this disease was not consistently prevented and there was too much chemical injury (see Table 12) to most species of plants the seeds of which were sown 1 to 3 weeks after soil treatment.

Gratz (39) made the similar observation that enough of this chemical to kill plants (cabbage) was not enough to prevent their infection by Rhizoctonia, and a heavy application used by Small (81) did not protect tomato seedlings against this fungus.

This is not a chemical which, in effective amounts, may be used safely with most species immediately before seeding, and the time interval between soil treatment and seeding with safety is not likely to be short. It is, of course, less injurious to some species than to others, and the one least injured in these experiments (see Table 12) was ten-weeks stock. According to Loew (59), the length of time which is necessary between soil treatment with calcium hypochlorite and seeding, may be affected by the character of the soil, with the interval shorter in soils rich in humus and low in clay. He used about 19 gm. per square foot without injury to cabbage and beet, but these were not planted until 2 months after soil treatment—a delay which many growers would consider as undesirable as the risk of damping-off without any treatment.

Other Calcium Salts

As was discussed earlier, it does not appear that damping-off is ordinarily controllable by the use of calcium in the form of lime. Albrecht and Jenny (4) observed less damping-off of soybean, however, when they used calcium acetate and calcium chloride and they concluded that calcium concentration is more important than H-ion concentration in affecting damping-off. They made no observations as to infecting fungi, and their seedlings often damped-off in spite of sterilization of soil and seeds by other means. It is, therefore, at least possible that fungi may not have been the cause at all, for plant ailments of very different origin may be much alike in symptoms.

The calcium salts here named were applied by the writer to soil inoculated with Pythium and this fungus was isolated from seedlings which damped-off. The disease was not controlled by calcium chloride in amounts sufficient to injure Ageratum, Myosotis, and mignonette. Calcium acetate was less injurious, but heavy applications, up to 30 gm., did not control damping-off.

Calcium sulfate, gypsum, even 50 gm. per square foot, also failed to control damping-off, although 20 to 35 gm. did improve the growth of seedlings of sweet pea, but not of lavender and Delphinium. It is occasionally recommended in horticultural literature for the control of root rots of pea, and the growth of legumes in some soils has, according to Cubbon (24), been benefited by it; but the results in this work were not such as to warrant its recommendation as a soil fungicide.

Riviere and Pichard (77) concluded that calcium sulfite has a temporarily antiseptic action in soil. Apparently it is not very pronounced, however, for 10 to 25 gm., used in these experiments, did not control damping-off satisfactorily.

Potassium Permanganate

This is sometimes applied to soil by British horticulturists (83, 22) with the object of controlling damping-off. It is occasionally mentioned in the American literature, also; and there are statements, usually without supporting evidence, to the effect that potassium permanganate is a soil disinfectant. Thus Connors (21) believed that its fungicidal value is known; Hunn (49) asserted that it sterilizes a rooting medium (for cuttings); and Wiggin (98) was of the opinion that plant propagators can check damping-off with it.

Such really experimental evidence as was found in the literature points in the other direction and leads to the belief that potassium permanganate is not a reliable soil disinfectant. According to McCallan and Wilcoxon (64), solutions were not toxic to spores of Botrytis and Sclerotinia which were suspended in them; and White (96) found it ineffective in preventing infection of cuttings by Pythium. Concentrations of solutions and rates of application are variously expressed, but, when translated to number of grams per square foot of soil, 3.5 gm. potassium permanganate did not satisfactorily protect cuttings of geranium against Pythium (Gill, 37); Brien and Chamberlain (13) were unable to protect tomatoes against Pythium by 13 gm.; 20 gm. had no apparent sterilizing action on soil in Buddin's experiments (16), and failed to protect tomatoes against Rhizoctonia in the work of Small (81).

As used by the writer, potassium permanganate up to 50 gm. per square foot never controlled damping-off caused by Pythium and Rhizoctonia. It is unlikely that heavier applications could be used, for growth of most species was injured by 50 gm., while the germination of China aster was injured by 40 gm. and that of sweet pea by 30 gm.

There was, however, improved growth of Aubrietia, hollyhock, beet, and cucumber with 15 and 20 gm.; and it should be noted in this connection that Webster and Robertson (94) observed marked growth response of various plants to potassium permanganate. They concluded, from work with a species of Opuntia, that the good effect of the permanganate on growth is not wholly, or is something more than, manurial.

Potassium permanganate, in these experiments, made a slightly acid soil less acid. Chadwick (17) concluded that the effect of this salt on the reaction of a medium is not the same for all media, and his results, like those of the writer, make it appear that the statement by Hunn (49) that potassium permanganate acidifies a rooting medium is not always correct.

On the basis of these results, potassium permanganate cannot be recommended for the protection of seedlings against damping-off. This is not to say that it is always useless in the propagation of plants vegetatively, for there is then more involved than the mere prevention of damping-off and there is evidence in the literature that potassium permanganate sometimes improves the rooting of cuttings. Curtis (25) found that to be the case when it was applied to cuttings of woody plants. Carnation cuttings rooted better when Connors (21) watered the rooting medium with a solution of potassium permanganate, about 3.5 gm. of the salt per square foot; and in the experiments of Chadwick a solution of about 1 pound in 15 gallons, 2 quarts per square foot, improved the rooting of cuttings of most species of woody plants used by him. It does not follow that potassium permanganate is a soil fungicide, and the explanation of Curtis seems adequate. He noted that cultures containing the permanganate were not sterile and suggested that its beneficial effect on rooting may be due to its increasing the respiratory activity of the cutting by hastening oxidation. This view seems to be strengthened by the results of Zimmerman (103), who found that oxidizing agents such as potassium permanganate improve the rooting of cuttings, but that aeration alone may be even more effective.

Charcoal

Charcoal is mentioned at this point, for it too is occasionally recommended, as by Macself (61), for a soil treatment to check the spread of damping-off, although there seems to be little or no experimental evidence on which to base such a recommendation. Chupp (19) observed that there was almost no damping-off in a steamed soil with which a grower had mixed powdered charcoal, but the steaming alone could, of course, account for that, and Chupp did not assert otherwise.

Powdered wood charcoal 1 to 4 ounces per square foot, worked into soil before seeding, did not control damping-off or improve germination. Powdered charcoal is sometimes used, as Taylor (84) says, with rooting media for cuttings; but when the writer so used it, up to 3 ounces per square foot, there was no significant effect on the rooting of cuttings (taken July 1) of *Enkianthus subsessilis, Lonicera syringantha, Rhododendron arbutifolium* and Persian yellow rose.

Charcoal is said (2) to lessen the danger of injury to plants by a too acid soil; but if so, it is not by changing soil reaction, for, in these experiments, 4 ounces or less did not affect pH values of soil 54 days after soil treatment.

Charcoal 1 to 4 ounces did not affect growth of seedlings of Aubrietia, heliotrope or sweet pea, but did significantly improve the growth of nasturtium. This improvement was first evident 2 or 3 weeks after germination and continued for 5 to 10 weeks or as long as the plants were under observation, with most benefit from applications of 2 to 4 ounces.

Aluminum Sulfate

Several investigators (97, 56, 52) have successfully used aluminum sulfate for the protection of conifers against damping-off. Not much use has been made of it with other species, although Weindling and Fawcett (95) found that 30 gm., raked into soil before seeding, protected citrus seedlings against Rhizoctonia.

Aluminum sulfate, in solution, was applied to soil before seeding. Damping-off caused by Pythium and Rhizoctonia, more often by the latter, was not affected by 10 or 15 gm., was less severe with 20 or 25 gm., but was never eliminated by less than 30 gm. The exact quantities necessary would probably not be the same in all soils, for Jackson (52) found that an application which lessened the severity of damping-off of conifers at pH 3.5 was not as effective at pH 6.5. By preventing some pre-emergence damping-off, 25 to 30 gm. improved the germination of Calendula, China aster, several species of Dianthus (see Table 13), foxglove, sweet pea, and Nicotiana.

There was no injury to germination of any species by 28 gm., nor to Calendula, China aster, and Nicotiana by 35 gm., while seeds of all species of Dianthus used germinated without injury by 44 gm.

Soil pH values were lowered, in 8 weeks, from an initial value of pH 6.5 to pH 6.0 by 20 gm. and to pH 5.7 by 25 gm. These effects might, of course, be different in different soils.

There was more injury to growth than to germination. Results are recorded in Table 13. Seedlings of beet, a species which McLean and Gilbert (66) found very subject to injury by aluminum, and China aster were injured by 20 gm., and Petunia, Nicotiana and *Primula polyantha* were not much less sensitive. It is not likely that aluminum sulfate can be used safely for the protection of such species. Calendula and sweet pea were less injured, and most tolerant of all were the species of Dianthus, for they were not injured by 44 gm. and their early growth was, in fact, improved by 20 gm.

TABLE 13.—EFFECT OF ALUMINUM SULFATE ON GROWTH OF DIFFERENT SPECIES

Species	Not injured by	Injured by
	Gm.	*Gm.*
Calendula	30	35
China aster	15	20
Dianthus sps.*	44	—
Foxglove	20	28
Laburnum	—	25
Lupine	20	30
Nicotiana	20	25
Petunia	15	25
Primula polyantha	20	25
Snapdragon	28	35
Sweet pea	30	40
Beet	15	20
Cucumber	20	30

*All the species of Dianthus which are named in the appendix.

Copper and Copper Salts

The copper salts here mentioned were very thoroughly mixed with soil which had been inoculated with Pythium, for, as was shown by Hunt and his co-workers (50), their penetration in and through soil is poor. No use was made of Rhizoctonia, against which several investigators (70, 85, 79, 38, 97, 89) have found copper salts rather ineffective. Especial attention was paid to their effects on germination and on growth of seedlings, for the literature suggests that copper in soil-fungicidal quantities may be far from safe to some species.

Metallic Copper Powder[1]

This metallic copper, manufactured electrolytically in crystalline form, gave some degree of control of damping-off when not less than 10 gm. was applied to soil before seeding; but the growth of several species (mignonette, foxglove, sweet alyssum, *Viola cornuta*, snapdragon, heliotrope, *Pentstemon ovatus*, China aster, sweet pea, and Calendula) was injured by it.

Cuprous Cyanide

There was little or no damping-off with 2 gm. cuprous cyanide; but no salt of copper used was any more toxic to plants, especially to Ageratum, Petunia, Salpiglossis, beet, and cucumber, and 2 gm. injured germination of beet and cucumber more than did 3.5 gm. copper carbonate. Hollyhock was the only species satisfactorily protected by cuprous cyanide without some chemical injury.

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[1] Copper powder, "B" metal from United States Metals Refining Company.

Copper Sulfocarbolate

Copper sulfocarbolate, up to 4.5 gm., gave less satisfactory control of damping-off than did some other copper salts; and 4.5 gm., although not at all injurious to hollyhock, was injurious to ten-weeks stock, Petunia, Myosotis, Ageratum, Salpiglossis, sweet pea, beet, and cucumber.

Copper Aceto-arsenite

Copper aceto-arsenite (Paris green) 0.5 gm. did not control damping-off, but there was little of the disease with 1.0 gm., less with 1.5 or 2 gm., and usually none with 2.5 gm. or more. Applications of more than 1.5 gm. were unsafe, however, for they injured the germination of seeds of all species used except hollyhock. Harmful effects on growth were even more evident, as little as 0.5 gm. injuring pyrethrum and Myosotis, while 1.0 gm. was toxic also to seedlings of sweet pea, Salpiglossis, Ageratum, marigold, Leiophyllum, Laburnum, and arbor-vitae. Hollyhock was the species most tolerant of this as of the other copper salts, being uninjured by 2.0 gm., and it was the only species protected against damping-off by copper aceto-arsenite without some chemical injury.

Copper Carbonate

According to Newhall and his associates (70), copper carbonate may be applied to soil at the rate of 1 pound to 100 square feet, which is about 4.5 gm. per square foot; but, as used by other investigators (71, 6), 4.0 gm. injured tobacco, and in the work of the writer, more than 4.0 gm. injured the germination of all species except hollyhock. Even lighter applications interfered with growth, cucumber being injured by 2.0 gm., Delphinium by 3.0 gm., and Ageratum, Petunia, and Salpiglossis by 3.5 gm.

Of the species used, only hollyhock and possibly beet showed sufficient lack of chemical injury to suggest that copper carbonate in effective quantities may be used safely with them, for less than 4.0 gm. did not satisfactorily control damping-off. Hollyhock was the species most tolerant of this as of other copper salts, and although injured by 6.0 gm., it was not at all affected by 5.0 gm. or less.

Copper Sulfate

Copper sulfate 3 to 4 gm. usually lessened the severity of damping-off, but the disease was not often wholly controlled by less than 4.5 gm. Germination was also improved by 3 to 5 gm. and with this as with other copper salts, there was usually less chemical injury to germination than to growth.

Copper Sulfate Grams	Growth Injured	Copper Sulfate Grams	Growth Injured
1.5	Canterbury bells	3	Snapdragon
			Mignonette
2	*Anemone coronaria*		Ageratum
	Viola cornuta		Salpiglossis
2.5	Calendula	3.5	Sweet pea
	China aster		Cucumber
			Beet

Hollyhock, growth of which was uninjured by 4.5 gm., was the only species with which copper sulfate, in quantities really effective against damping-off, was used without too much chemical injury.

Copper-lime Dust

An English recommendation which is mentioned by Newhall and his associates (70) calls for about 22 gm. (per square foot) of a 10-90 copper-lime dust. This is equal, on basis of copper content, to about 11 gm. of a 20-80 dust, which was used in these experiments. Such an application did not prove heavy enough, for less than 20 gm. of the 20-80 dust did not give satisfactory control of damping-off. Control was usually good with 25 and 30 gm., not so good with 20 gm.

Applications up to 30 gm. did not interfere with the germination of seeds of *Anemone coronaria*, Delphinium, Salpiglossis, hollyhock, mignonette, and *Lilium tenuifolium* and, by the prevention of some pre-emergence damping-off, often improved it. Statice and sweet pea, however, were injured by 20 gm., beet and cucumber by 25 gm., and hollyhock and mignonette were the only species not injured by 30 gm.

When effects on both damping-off and growth of seedlings are considered, copper-lime dust gave as good results as did any copper fungicide. Its use, in quantities really effective against damping-off, would, however, have to be limited to those species of plants which are least susceptible to chemical injury by it. It makes soil less acid, and an application of 25 gm. to soil with an initial pH value of 6.5 resulted in a pH value of 6.8 eight weeks later. For this reason, copper-lime dust would not be indicated for use with species known to prefer a more acid soil.

With copper-lime dust as with the copper salts above mentioned, the greater tolerance of hollyhock was evident. It is of interest in this connection that Eriksson (34) reported no injury to hollyhock growing in soil which he watered with a 0.3 percent solution of copper sulfate, for, if such watering was long continued, there must have been a considerable accumulation of copper in the soil about the roots of the plants. Cotton, another member of the Malvaceae, may be tolerant of copper also, for in the work of Fikry (35), cotton plants were not injured by a heavy application of copper sulfate to the soil in which they grew.

Copper Oxalate

Copper salts, in spite of the limitations above mentioned, may sometimes be useful in protecting against Pythium the seeds and seedlings of such species as germinate so slowly that a volatile chemical would be gone from the soil long before protection was most needed. Copper oxalate, 6 gm., was applied to soil immediately before sowing seeds of the umbrella pine. They germinated 3 months later. Damping-off was well controlled, without chemical injury, and the stand was increased nearly nine-fold compared with the checks, while there was little if any benefit from acetic acid. Quick (74) has used copper oxalate similarly and successfully as a soil fungicide for the protection of seeds of *Ribes roezlii* Reg. during their stratification.

Mercuric Chloride

Mercury salts are apparently more effective against Rhizoctonia in the soil than are copper salts; but mercury salts may be just as injurious to plants, and it is important to know the quantities which may be expected to be effective against fungi and at the same time safe to use.

In the experiments of Jackson (51), China asters were protected against Fusarium wilt by "soaking" the soil with a 0.1 percent solution and there was no chemical injury. One quart of such solution contains about 0.95 gm. of the salt and that is the quantity which, in the work of Beach (8), protected lettuce against Sclerotinia although plants were injured chemically. A dilution of 1:1600 had some effect in protecting violets against Rhizoctonia (72), and as little as 0.12 gm. (per square foot) was effective, in the experiments of Wiant (97), in protecting conifers against Rhizoctonia. Stands of tomato were injured by 0.44 gm., not by 0.22 gm., as used by Thomas (85); and as light an application as 10 to 15 pounds per acre (about 0.10 to 0.15 gm. per square foot) was observed by Macleod and Howatt (60) to be associated with reduced yields of potatoes.

The writer applied mercuric chloride, 1 or 2 quarts of the solution per square foot, to soils which had been inoculated or were naturally infested with both Pythium and Rhizoctonia. There was sometimes some damping-off with 0.95 gm., equal to 2 quarts of a 1:1000 solution, or 1 quart of a 1:2000 solution per square foot. There was little or no damping-off with applications heavier than 1.0 gm. per square foot, but such applications were very harmful to germination or growth of some of the species named in Table 14, although a number of species, notably Salpiglossis, Petunia, lupine, sweet pea, and English daisy, finally outgrew most of the earlier chemical injury.

TABLE 14.—EFFECT OF MERCURIC CHLORIDE ON GERMINATION AND GROWTH

Species	Germination		Growth	
	Not injured by	Injured by	Not injured by	Injured by
	Gm.	*Gm.*	*Gm.*	*Gm.*
Arabis	—	1.5	—	1.5
Canterbury bells	—	1.0	—	1.0
Dianthus chinensis and *D. plumarius*	2.5	—	1.5	2.0
English daisy	3.0	—	1.0	1.5
Foxglove	—	1.5	—	1.5
Heliotrope	—	1.5	—	1.5
Lupine	2.5*	—	1.75	2.2
Pansy	1.5	2.0	—	1.0
Petunia	1.7*	2.5	1.5	2.5
Salpiglossis	2.0*	—	2.2	2.7
Sweet pea	2.5*	3.0	2.0	2.2
Rhododendron molle and *R. yedoense* var. *poukhanense*	—	1.5	—	—
Beet	2.5	3.0	—	2.0
Cucumber	1.7	2.0	—	1.5

*Germination improved.

The species least injured as regards growth and most benefited as regards germination were Salpiglossis, Petunia, lupine, and sweet pea, and with these the use of mercuric chloride as a soil fungicide appears to deserve further investigation.

Zinc Sulfate

As a supplement to seed treatment with red copper oxide, which does not wholly prevent post-germination damping-off, Horsfall (48) successfully used zinc oxide 0.5 to 1.0 ounce per square foot, applying it to the surface of the soil after seeding. He did not find zinc sulfate safe although germination of tomato was in some cases improved and damping-off was at least partly controlled by 10 gm.

The sulfate is, of course, much more soluble and might, in the absence of seed treatment, be expected to give more protection than the oxide. Zinc sulfate was accordingly used in these experiments with the thought that it may be less harmful to some species than to tomato and useful at least with them. It was always applied to soil before seeding and in solution.

Post-emergence damping-off, caused principally by Pythium, partly by Rhizoctonia, was not completely controlled by less than 16 gm., but there was usually some control of pre-emergence damping-off, with germination improved accordingly, by 12 gm. or more. Zinc sulfate, however, in quantities effective against damping-off, interfered somewhat with the growth of most species used, as shown by the following tabulation.

Zinc Sulfate	Growth Injured	Growth Not injured
10 gm.	Heliotrope Physostegia Ten-weeks stock China aster English daisy	
12 gm.	Foxglove Beet Cucumber	Pansy Sweet pea *Iberis sempervirens* *Oenothera missouriensis* Sweet William
14 gm.		Sweet William Sweet pea

Sweet William and sweet pea were the only species which were at all satisfactorily protected against damping-off by zinc sulfate without some chemical injury.

Sulfuric Acid

Sulfuric acid is known to have some value as a soil disinfectant and it has been used by other investigators (43, 88, 42) for the control of damping-off of conifers. Recommended rates of application per square foot vary considerably, from about 3 to about 14 gm., diluted with water and applied to soil at the time of seeding. Even these quantities have been found to be unsafe in some soils and with some species, and as little as 5.1 gm. was observed by Toumey and Li (88) to retard the growth of seedlings of white pine, spruce, and hemlock. Not much use seems to have been made of it with herbaceous plants.

The writer diluted sulfuric acid (95 percent, sp. gr. 1.84) so as to give the desired number of grams of this acid per square foot when 2 quarts of the solution were applied. Seeds were sown within 24 hours after soil treatment. Soils used had initial pH values of 6.4 to 6.6. Soil pH values, 8 weeks after treatment in a typical instance were: check, 6.4; 6 gm., 6.2; 9 gm., 5.7; 12 gm., 5.5; and 16 gm., 5.0.

The severity of damping-off, most of it caused by Pythium, some by Rhizoctonia, was lessened by 9 gm., but infection was not satisfactorily controlled by less than 12 or, more often, 15 gm.

These and even smaller quantities were injurious to most species. Growth of beet and cucumber was retarded by 6 gm., that of English daisy by 9 gm. Twelve grams interfered with the germination of Delphinium, Salpiglossis, *Viola cornuta*, and Canterbury bells, but not of Dianthus, the genus least injured by this acid. Growth of *Dianthus barbatus*, *D. latifolius*, *D. plumarius* and *D. alpinus* was a little injured at first by 14 gm., but most or all of this injury was later outgrown.

Sulfuric acid 10 gm. improved germination of seeds of *Rhododendron calendulaceum*, *R. carolinianum*, *R. catawbiense* and *R. Schlippenbachii* in a sandy, peaty soil (initial pH value 5.8), without injury to growth. The use of sulfuric acid, in this way, with ericaceous plants, is now being investigated further

Of the other plants used, only the species of Dianthus were sufficiently tolerant of sulfuric acid to suggest that it may possibly be used with them.

Sulfur

As is well known, the addition of sulfur to soil may, by increasing soil acidity, have an inhibiting effect on certain soil fungi. There is no reason to suppose that damping-off would be controlled in this way, however; for, as has already been noted, the disease may be severe even in an acid soil, and Buddin (16) concluded from his work that sulfur does not sterilize soil. Townsend (89), too, found sulfur ineffective in protecting (lettuce) plants against a disease caused by Rhizoctonia. It is nevertheless occasionally mentioned in horticultural literature as a soil treatment for the prevention of damping-off and some experimental use was accordingly made of it.

Flowers of sulfur, up to 20 gm. per square foot or more than 1900 pounds per acre, was well mixed with soil immediately before seeding. Soil pH values, 5 weeks later, were lowered from 6.3 to 5.8 by 8 gm. and to 5.0 by 20 gm., but damping-off, caused by Pythium, was no less severe with 6 to 20 gm. than it was in untreated soil.

Six grams (or more) of sulfur interfered with the growth of beet and cucumber seedlings, but foxglove was uninjured by 8 gm., and sweet pea, for the first ten weeks, by 10 gm.

SUMMARY

Damping-off is not altogether controllable in practice by regulating and adjusting the environment (soil temperature, moisture, and reaction), for conditions preferred by the fungi are too nearly the same as those preferred by the plants. For example, the watering of small seeds from below is advisable for other reasons, but damping-off is not always prevented by it.

In washed sand or in sand-sphagnum or in sand-peat moss, there was very little damping-off as compared with that in soil. However, growth of all species was poorer in sand, even with nutrient, than in soil and usually better in sand-sphagnum or in sand-peat moss (with nutrient) than in sand.

To lessen the cost of using soil which has been purchased already sterilized, it was sometimes diluted with washed sand. Growth of seedlings was satisfactory and there was no increase in damping-off.

Increase in knowledge of better methods of using old soil disinfectants and other chemicals, possible new soil disinfectants which may have more nearly ideal qualities, makes it evident that a soil treatment which is good for some species of plants may be not so good or even injurious to others. Thus charcoal, although not a fungicide, improved the growth of nasturtium; and calcium sulfate had a similar effect on sweet pea, but on sweet pea alone.

Damping-off was not controlled by calcium sulfate, acetate, or chloride or by materially raising soil pH values with hydrated lime.

The most common evidence of stimulation of growth of plants observed following the use of soil fungicides, occurred when Rhizoctonia, in untreated soil, so interfered with growth that plants in treated soil, and therefore free from the fungus, grew better. Exceptions are chemicals which contain nutrients as do calcium cyanamide and ammonium hydroxide.

Damping-off was well controlled by calcium cyanamide and more use might well be made of it when the necessary delay between soil treatment and seeding is not considered too objectionable. This is true also of ammonium hydroxide which prevented damping-off and was, as used, harmless to most species. Ammonium acetate was less effective.

Ammonium thiocyanate in the soil also remained toxic to plants for too long a time to be a good soil disinfectant, for there is more need of such as can be used at or about the time of seeding.

The time interval between soil treatment and seeding depends partly on the species of plant involved; and formic acid, formaldehyde, acetic acid (and vinegar) were, in general, less injurious to seeds which germinate slowly than to those which germinate rapidly.

Formic acid controlled damping-off and is not ordinarily harmful if worked into the soil before seeding.

Another promising material was salicylic acid. Final stands of seedlings were often much improved by it and it has the advantage of being readily applied to soil without the necessity of first preparing either a solution or a dust.

Tannic acid gave no evidence of being fungicidal, but growth of foxglove was benefited and it apparently improved the soil physically.

There were indications that less of a fungicide, for example formaldehyde, is necessary if not too much water is applied with it. Less than one-fifth as much formaldehyde as was formerly used controlled damping-off when the quantity of water used with it was also much reduced.

Damping-off was controlled by acetic acid dusts and they were not injurious to most species when applied to soil the day before seeding. They were, however, very toxic to softwood cuttings.

Undiluted vinegar, applied to soil immediately before seeding, controlled damping-off, usually without injury.

Quantities of acetic acid, formaldehyde, and other volatile chemicals which were safe enough if worked into the soil immediately before seeding were injurious if applied to the surface of the soil immediately after seeding, for they are then more concentrated near the seeds.

Crucifers were more often injured by acetic acid and by formaldehyde than were most of the other plants used.

Too little vinegar to prevent damping-off was injurious if applied after the emergence of seedlings.

Damping-off was well controlled by pyroligneous acid (from pine wood) and this was not injurious when applied to soil immediately before seeding.

Acetaldehyde was less toxic both to plants and to fungi than was formaldehyde and, in infested soil, sweet pea grew better with it. Sweet pea, germination and growth, was apparently benefited by ethyl alcohol also.

Calcium hypochlorite is not a chemical which, in effective quantities, may be used safely with most species immediately before seeding. The interval of time between soil treatment with calcium hypochlorite and seeding with safety is not likely to be short.

Heavy applications of potassium permanganate did not control damping-off, and its occasional recommendation for this purpose is not justified.

Inorganic salts, such as those of copper, may have a use in protecting seeds and seedlings of such species as germinate so slowly that a volatile chemical would be gone from the soil long before protection is most needed. Seeds of a species which required three months to germinate were not well protected by acetic acid, but were by copper oxalate.

Copper-lime dust, with other species, gave as good results as did any copper salt, but all salts of copper were too toxic to many species of plants, with hollyhock showing the greatest tolerance.

Aluminum sulfate in quantities injurious to many other species was perfectly safe with Dianthus. Species of Dianthus and species of Rhododendron were notably tolerant of sulfuric acid also. There was no evidence that sulfur is a soil disinfectant.

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APPENDIX

Ornamental Plants Used in the Experiments

Agapanthus africanus Hoffmg.	16
Ageratum Houstonianum Mill.	16, 19, 27, 30, 31
Althaea rosea Cav. Hollyhock	28, 30, 31, 32
Alyssum argenteum Vitm.	25, 26
A. saxatile L.	15, 23, 24
Anchusa azurea Mill.	20
A. myosotidiflora Lehm.	26
Androsace sarmentosa Wall.	15
Anemone coronaria L.	31, 32
A. Pulsatilla L. Pasque Flower	20
Antirrhinum majus L. Snapdragon	26, 30, 31
A. maurandioides Gray	16
Aquilegia vulgaris L. Columbine	13, 21, 22
Arabis albida Stev.	15, 21, 33
Arenaria grandiflora L.	15
Aubrietia deltoidea DC.	28, 29
Begonia tuberhybrida Voss. Tuberous-rooted Begonia	6
Bellis perennis L. English Daisy	5, 13, 19, 33, 34, 35
Berberis triacanthophora Fedde	13
Browallia americana L.	13
Calendula officinalis L.	4, 5, 12, 15, 16, 20, 25, 26, 29, 30, 31
Callistephus chinensis Nees. China Aster	13, 14, 15, 26, 28, 29, 30, 31, 34
Calluna vulgaris Salisb. Heather	13
Campanula Medium L. Canterbury Bells	5, 8, 18, 20, 23, 24, 25, 31, 33, 35
Centaurea Cyanus L. Cornflower	14, 15, 17
C. macrocephala Puschk.	26
Cerastium Biebersteinii DC.	13
Chamaecyparis obtusa Sieb. & Zucc.	13
Cheiranthus Allionii Hort.	12, 14, 20, 24
Chrysanthemum coccineum Willd. Pyrethrum	15, 31
Dahlia pinnata Gav.	13
Delphinium sp. Perennial Larkspur	7, 13, 14, 15, 31, 32, 35
Dianthus alpinus L.	29, 30, 35
D. arenarius L.	14, 17, 29, 30
D. barbatus L. Sweet William	7, 19, 29, 30, 34, 35
D. caesius Smith. Cheddar Pink	29, 30
D. chinensis L.	7, 29, 30, 33
D. deltoides L. Maiden Pink	29, 30
D. latifolius Hort.	29, 30, 35
D. plumarius L. Grass Pink	7, 29, 30, 33, 35
Digitalis purpurea L. Foxglove	18, 22, 23, 24, 25, 26, 29, 30, 33, 34, 35
Dimorphotheca annua Less.	14, 17
Enkianthus subsessilis Mak.	29
Erica carnea L. Spring Heath	13
Euonymus japonica L.	13
Felicia amelloides Voss.	13, 16, 20
Galega officinalis L. Goat's Rue	20

Heliotropum peruvianum L. Heliotrope ... 24, 26, 29, 30, 33, 34
Hesperis matronalis L. Rocket ... 13, 32
Iberis amara L. Rocket Candytuft ... 15
I. sempervirens L. Edging Candytuft ... 34
Ilex yunnanensis Franch ... 13
Ipomaea purpurea Lam. Morning-Glory ... 15
Laburnum alpinum Griseb ... 13, 22, 31
Lachenalia pendula Ait ... 16
Lathyrus odoratus L. Sweet Pea .. 13, 18, 19, 20, 21, 22, 23, 24, 25, 26, 29, 30, 31, 32, 33, 34, 35
Lavandula Spica L. Lavender ... 27
Leiophyllum buxifolium Ell ... 31
Lilium philippinense Baker ... 12
L. regale Wils ... 26
L. tenuifolium Fisch ... 32
Linanthus sp ... 13, 16, 20
Lobularia maritima Desv. Sweet Alyssum ... 19, 24, 25, 26, 30
Lonicera pileata Oliv ... 13
L. syringantha Maxim ... 29
Lupinus polyphyllus Lindl. Lupine ... 13, 14, 15, 23, 24, 33
Mathiola bicornis DC ... 13, 15
M. incana R. Br. var. *annua* Voss. Ten-Weeks Stock ... 5, 21, 22, 26, 27, 34
Mentha Requienii Benth ... 16
Mesembryanthemum lineare Thunb ... 14
Myosotis scorpioides L ... 27, 31
Nepeta Mussini Spreng ... 11
Nicotiana alata Link and Otto var. *grandiflora* Comes ... 8, 19, 29, 30
Oenothera fruticosa L. Sundrops ... 25
O. missouriensis Sims ... 34
Opuntia humifusa Raf ... 15, 16
O. vulgaris Mill ... 15, 16
Pentstemon ovatus Dougl ... 30
Petunia hybrida Vilm ... 19, 24, 30, 31, 33
Phlox Drummondii Hook ... 20, 22
Physostegia virginiana Benth ... 26, 34
Primula denticulata Sm ... 6
P. polyantha Mill ... 30
Ramondia pyrenaica Rich ... 6
Ranunculus asiaticus L ... 14, 15
Reseda odorata L. Mignonette ... 19, 23, 25, 27, 30, 31, 32
Rhododendron arbutifolium Rehd ... 29
R. calendulaceum Torr ... 13, 35
R. carolinianum Rehd ... 13, 22, 35
R. catawbiense Michx ... 13, 22, 35
R. molle G. Don ... 22, 33
R. Schlippenbachii Maxim ... 13, 22, 35
R. yedoense Maxim. var. *poukhanense* Nakai ... 33
Rosa foetida Herrm. var. *persiana* Rehd. Persian Yellow Rose ... 29
Salpiglossis sinuata Ruiz & Pav ... 5, 23, 24, 25, 30, 31, 32, 33, 35
Scabiosa atropurpurea L ... 24, 25, 26
Sciadopitys verticillata Sieb. & Zucc. Umbrella Pine ... 32

Sedum dasyphyllum L. 15
Silene acaulis L. 15
Statice pseudo-Armeria Paxt. 32
Tagetes patula L. Marigold 5, 19, 31
Thuja occidentalis L. American Arbor-vitae 13, 14, 15, 22, 31
Thunbergia alata Bojer 16
Thymus Serpyllum L. Thyme 3
Torenia Fournieri Lind. 12, 16
Tropaeolum majus L. Garden Nasturtium 26, 29
Verbena hybrida Voss. Common Garden Verbena 12, 14, 16
Veronica repens DC. 12
Viola cornuta L. 5, 19, 30, 31, 35
V. tricolor L. var. *hortensis* DC. Pansy 33, 34
Zantedeschia aethiopica Spring. Calla 16
Zinnia elegans Jacq. 5, 13, 14, 15

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

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The Carrot Rust Fly

By W. D. Whitcomb

The carrot rust fly is the most destructive insect pest of carrots, an important vegetable crop in Massachusetts. Information about its life history, habits, and methods of control by cultural practices and insecticides, reported herein, should enable carrot growers to avoid serious losses.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

RECOMMENDATIONS

FOR THE CONTROL OF THE CARROT RUST FLY

Cultural Practices

Do not plant carrots in cool, damp areas which attract the flies and favor their development.

If early carrots are planted, be prepared to use insecticides; if late carrots are planted, sow the seed about June 10 to avoid the attack of the first generation of the carrot rust fly. If the main crop is late carrots, do not plant small blocks of early carrots which may provide favorable breeding places for a large second generation of the pest.

Do not thin carrots at the height of the oviposition period of the carrot rust fly because this loosens the soil and provides protection to the flies while laying eggs in crevices in the soil.

Do not leave infested carrots in the ground at harvest. If they are worthless because of carrot rust fly injury, pull them and dispose of the carrots *immediately* so that the maggots in them will be killed. This may be done by burning with oil, burying with quick lime under a foot of *packed* soil, or feeding to livestock in the barn. Infested carrots discarded at sorting, or found in storage, should be treated in the same way, and boxes or bins in which infested carrots have been stored should be cleaned or fumigated with carbon disulfide.

Cultivate or harrow lightly in late autumn to expose larvae and pupae to weather, and plow deeply in spring to turn overwintering insects under the soil.

Insecticide Treatments

Treat carrot seed with powdered calomel, mixing ½ pound with each pound of seed just before planting, especially for early carrots.

On early carrots, if an expense of 5 to 10 cents per bushel is practicable, make three applications of derris or cube–clay dust containing at least 0.6 percent rotenone, at the rate of ¼ to ½ pound to each 100 feet of row, at weekly intervals beginning May 25 in early seasons and June 1 in late seasons; or make three applications of naphthalene flakes at the same weekly intervals using 1 pound to each 100 feet of row.

On late carrots, if an expense of 10 cents per bushel is practicable, make four applications of naphthalene flakes at weekly intervals beginning about August 1 and using 1 pound to each 100 feet of row. Ground tobacco containing 1 to 1¼ percent nicotine at the rate of 2 pounds to each 100 feet of row, or Scotch soot at the rate of 3 or 4 pounds to each 100 feet of row, can be used in the same way at a slightly greater cost.

THE CARROT RUST FLY

By W. D. Whitcomb,
Research Professor of Entomology

INTRODUCTION

The carrot rust fly, *Psila rosae Fab.*, is the most injurious member of the dipterous family Psilidae, called the rust fly family by some authors.

Although the yellowish hairs on the body of adults impart a somewhat rusty appearance to the fly, it is apparent that the rusty color which appears on the flesh and skin of carrots and parsnips after feeding by the larva is more responsible for the name. These rusty scars are not characteristic of rust fly injury only, but may be produced by any kind of injury to the skin of carrots and parsnips. Similar rusty scars can be made on carrots by pricking the skin with the point of a knife and scratching the surface with the fingernail. Many of the habits of this fly — such as the laying of eggs on the soil and crown of the plant, feeding on the roots by the larva, and pupation in the soil near by — are very similar to the habits of the cabbage maggot, the onion maggot, and the seed corn maggot; and it is suggested that, from the standpoint of both the economic entomologist and the vegetable grower, a very appropriate and practical common name would be the *carrot maggot.*

HISTORY AND DISTRIBUTION

The carrot rust fly was originally described in 1794 by Fabricius (7) as *Musca rosae* and in 1805 (8) this was changed to *Tephritis rosae*. About 1835 it was placed in both the genus *Psilomyia* and the genus *Scatophaga* by other authors, but since 1880 it has been universally known as *Psila rosae* Fab.

The original habitat of *Psila rosae*, according to Fabricius, was Kilia in Bessarabia, which was formerly a province in southwestern Russia but is now controlled by Rumania. In 1889 the habits of this insect and its injury to carrots were described by Ormerod (22) in England, and at that time it had become a well-known pest of carrots and parsnips in Germany and the British Isles.

No attempt has been made to trace the history of *P. rosae* in Asia, Africa, or South America, but in 1931 an infestation at Auckland, New Zealand, was reported by J. Muggeridge (21), and the history of this insect in North America indicates that it is likely to be present in any part of the world where climatic conditions are suitable. Like many other root maggots, it thrives in cool, damp locations, and it is interesting to note that it has never been reported south of 40° latitude in North America.

Information on the distribution of this insect in North America has been secured through the courtesy of the entomologists in the various States and Provinces, and the Insect Pest Survey of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

CANADA

Psila rosae Fab. was first reported in North America in 1885 by Dr. James Fletcher, Dominion Entomologist of Canada (10) who identified specimens reared from carrots purchased in the market at Ottawa. Much injury occurred in the vicinity of Montreal, Quebec, and Ottawa in 1886 (11), but this pest apparently did not cause serious losses again until 1895-99 when another outbreak occurred

(12, 13). By 1899 the insect had become so common in Ontario, Quebec, and New Brunswick that its establishment in eastern Canada was unquestioned. Another widespread and destructive outbreak was reported in 1928-1930. Although it has been found in Washington near the boundary of British Columbia, the entomologists in that Province have no record of its presence in western Canada.

TABLE 1. SUMMARIZED HISTORY OF THE CARROT RUST FLY IN NORTH AMERICA

State	FIRST OCCURRENCE Locality	Year	Periods of Serious Damage
Canada			
Ontario	Ottawa	1885	1886–1899
Quebec	Montreal	1886	1895–1899
New Brunswick	Upper Sackville	1894	1895–1899
United States			
Maine	Pittsfield, Somerset Co.	1893	1926–1930
New York	Broadalbin, Fulton Co.	1901	1926–1930
New Hampshire	Franconia	1902*	Recorded as minor pest
Washington	Nooksack, Whatcom Co.	1908	1929–1936
Massachusetts	Andover	1913	1926–1930
Vermont	St. Albans	1913	Not recorded as pest
Michigan	Sault Ste. Marie	1914	1927–1930
New Jersey	Passaic County	1920	1927–1928
Pennsylvania	Adams County	1921	1927–1928
Oregon	Corvallis	1921	Not recorded as pest
Rhode Island	Newport	1923	1927–1930
Connecticut	Winsted	1927	1927–1930
Ohio	Akron	1930	1930–1931
Idaho	Moscow	1931	Not recorded as pest
Colorado	Museum specimen reported		Not recorded as pest

*Museum specimen collected. First infestation in carrot reported from Manchester in 1915.

UNITED STATES

Maine.— The occurrence of the carrot rust fly in the United States was first reported in April 1893 by Prof. F. L. Harvey of the Maine State College (19), who identified it from specimens reared from carrots grown and stored at Pittsfield, Somerset County, Maine. No further report was made until 1911, but it did not become economically injurious until 1928 and 1929. Since that time it has been observed occasionally but not in abundance.

New York.— The first New York infestation was found at Broadalbin, Fulton County, in the fall of 1901. Damage occurred on celery, this being the first record of injury to that vegetable, and a field of 60,000 celery plants was generally infested. This outbreak was investigated by Dr. E. P. Felt (9) New York State Entomologist, and by Dr. F. H. Chittenden (4) of the United States Bureau of Entomology, and the latter's report was the most complete discussion of this insect in America at that time. Glasgow and Gaines (18) state that the carrot rust fly has increased steadily since its introduction, and in 1929 it was considered a limiting factor in the growing of carrots in the large carrot-growing sections of the State.

New Hampshire.— A single specimen of *P. rosae* in the National Museum was collected at Franconia, New Hampshire, in 1902, but it was not recorded as causing damage to carrots until 1915 at Manchester. At present, this insect has been found in eleven towns in the State and undoubtedly it would become a serious pest if carrots were grown more extensively.

Washington.— Specimens in Dr. A. L. Melander's collection were taken in May 1908 at Nooksack, Whatcom County, and in May 1910 from Olga, on an island in Puget Sound. It was first reported as injuring carrots in 1929 and has increased in destructiveness each year. In 1936 it was found in Lewis County near the Columbia River, and most carrot plantings in the Puget Sound section were infested.

Massachusetts.— The first flies reported in Massachusetts were reared in September 1913 from maggots in carrots grown near Haggett's Pond, Andover, and are now in the Boston Museum of Natural History. From 1926 to 1930, however, infested carrots were observed and reported throughout the State, and during this period vegetable judges at agricultural fairs where the best carrots were displayed reported injury by the carrot rust fly in nearly every county. In fact, it was difficult to purchase in the market local grown carrots which were entirely free from evidence of attack. Since 1930 injury by this pest, although still to be found, has decreased greatly.

Vermont.— Although no records of injury to carrots are available from Vermont, specimens in the Boston Museum of Natural History were collected at St. Albans in 1913 and at Bennington in 1915.

Michigan.— Infested carrots at Sault Ste. Marie, found in June 1914, constitute the first record of this pest from Michigan, and it did not appear again until 1929 at Alpena and 1930 at Petoskey (23). Apparently, it has been confined to small areas in this State and, although threatening, it has not yet become a serious pest.

New Jersey.— The carrot rust fly has been known to be present in New Jersey since June 1920 when it was found in Passaic County. Infestations have been recorded at intervals through the northern two-thirds of the State, but the injury to carrots has been variable and generally slight.

Pennsylvania.— Records of injury by the carrot rust fly in Pennsylvania start in 1921 when it was found in Adams County, with the majority of the infestations occurring in 1927 and 1928. Altogether it has been found in twelve counties, mostly in the northern part of the State. The infestations in Adams County and Fulton County constitute the most southern known records for this insect in the United States, being located at approximately 40° north latitude.

Oregon.— In a list of *Diptera* found in Oregon, published in 1921 by Cole and Lovett (5), *Psila rosae* is recorded from Corvallis with a note that it is sometimes of economic importance. No other record of its occurrence in that State has been found, and a survey in 1937 failed to find any evidence of this insect.

Rhode Island.— The first record in Rhode Island refers to specimens collected at Newport in December 1923. Since that time, occasional damage to carrots in the vegetable-growing areas has been observed by County Agricultural Agents, but apparently it never became so destructive as in Massachusetts.

Connecticut.— Infested carrots and parsnips were observed in Winsted and New Haven in 1927, and slight infestations were reported until 1931 (2). No evidence of this insect has been recorded since and it is not considered an important pest in Connecticut.

Ohio.— Reports by Houser and Parks in the winter of 1931 refer to infestations in stored carrots grown at Canton and Akron during the previous summer and indicate that growers had observed damage in 1930. In 1932 it was considered a serious pest of carrots in the northeastern part of the State. Injury was most severe on carrots remaining in the ground late in the fall, and parsnips and celery were slightly damaged.

Idaho.— A museum specimen was collected at Moscow, October 5, 1931, but no reports of damage to vegetables are known.

Colorado.— Melander (20) lists museum specimens of *P. rosae* from Colorado but no other report of its occurrence in this State has been secured.

Indiana, Illinois, Wisconsin.— In 1931 and 1932 entomologists in these states reported to the Insect Pest Survey, United States Department of Agriculture, that although they were on the lookout for this pest no injury by it was known to occur nor were there specimens in the insect collections.

HOST PLANTS

Serious injury by the carrot rust fly, causing a definite loss to the grower, has been observed on carrots, parsnips, and celery. In Massachusetts severe damage to celery has occurred rarely, especially when one considers that about 500,000 boxes are produced annually; but in New York heavy infestations have been reported. Considerable damage to parsley and celeriac occurred in the experimental plantings, and a slight chewing on the surface of the roots and crown of coriander, caraway, fennel, and dill was observed. Even though such injury was found on 52 percent of the coriander plants in 1928, it could not be called commercially destructive, and there is no definite record that the carrot rust fly developed to maturity in these herbs.

Pettit (23) states that it has been reported attacking wild carrot, but, although this plant grows abundantly in eastern Massachusetts, *Psila rosae* has not been found or reported breeding in it here (24). Chittenden (4) quotes a Scandinavian

TABLE 2. RELATIVE SUSCEPTIBILITY OF HOST PLANTS OF THE CARROT RUST FLY

Waltham, Mass. 1928–1932.

	DEGREE OF INFESTATION — PERCENT							
	1928		1929		1930		1932	
HOST PLANT	Slight	Moderate and Severe	Slight	Moderate and Severe	Slight	Moderate and Severe	Slight	Moderate and Severe
Carrot	0.00	90.00	13.09	61.78	1.00	14.00		
Parsnip	9.80	29.42	1.00	10.00	5.00	15.00	0.50	2.00
Parsley	17.65	23.53	14.00	19.00	37.93	0.00		
Celeriac			9.00	28.00			0.00	0.00
Celery (Early)	13.21	13.21	*	0.00				
Celery (Late)	16.67	0.00						
Fennel	9.16	0.76	3.53	0.00				
Coriander	52.69	0.00						
Caraway	23.70	0.00	3.00	1.00				
Dill	8.47	0.00						

*33 plants showed slight injury to roots, which was suspected but not definitely determined as caused by *P. rosae*.

report that this species was reared from turnip and rape, and Pettit (23) refers to a report of it in potato; but in Massachusetts it has been found attacking only plants of the botanical family *Umbelliferae*, and evidently the members of this family are at least preferred as food.

SUSCEPTIBILITY OF VARIETIES OF CARROTS

Test plantings of strains and varieties of carrots were made at Waltham from 1929 to 1932 and records taken on the infestation by both the first and second generation of the carrot rust fly. In 1929 the field infestation was quite heavy and resulted in serious injury to 46 and 47 percent of the plantings of Nantes and Henderson's Intermediate. In 1930, 1931, and 1932 the field infestation was much lighter, and the injury to the various varieties of carrots was nearly equal. The last five strains of garden carrots listed in Table 3 were planted only in 1932 when the infestation was very light, and consequently the results are not significant, although 10 percent injury to Table Gem by the second generation in 1932 indicates probable severe injury to this carrot if subjected to a heavy infestation.

Of the garden varieties, it is apparent that the short, thicker varieties such as Chantenay and Scarlet Horn are less seriously damaged than the longer varieties such as Hutchinson and Intermediate, and yield records from Nova Scotia (1) confirm these observations.

At Waltham the stock carrots were generally more heavily infested than the garden carrots, as a group. Gorham (correspondence) states that in New Brunswick the white carrots suffer less injury than the red carrots, but at Waltham the White Mastodon and White Belgian varieties were very severely damaged in some cases and suffered more injury than the Long Orange Belgian.

NATURE OF INJURY

Plants are damaged only by the feeding of the larva, and on such crops as carrots and parsnips the injury occurs entirely below the surface of the ground (Plate 1 and 3). The first feeding causes narrow rust-colored furrows in the outer epidermis. These furrows are about 1/16 inch deep and may be round, narrow trails or blotchy, irregular areas with the epidermis broken in many places. They tend to proceed horizontally but are not consistent in this respect. In young, tender carrots the root just above the growing tip is generally attacked, and, if the plant is not killed by this injury, a stunted, bulbous, or irregular-shaped carrot results (Plate 2). In mature carrots tunnels may be made in any part of the root, and in severe infestations the tunnels may extend through the root from one side to the other, although this seldom occurs in types having a distinct fibrous core (Plate 4).

When infested carrots are stored in the fall, many larvae in them are still immature and continue feeding while the roots are in storage. In fact, it was injury of this kind which resulted in the first discovery of this insect in Canada and Maine. In light infestations, the presence of the maggots is often unnoticed at harvest, and much unexpected damage from late feeding by the maggots is found when the carrots are removed from storage.

The foliage of infested carrots, especially that of immature plants, is usually thin and often has a red or yellow color which is more pronounced in the older leaves.

Parsnips are injured in the same way as carrots, (Plate 1). In celery and parsley, the feeding roots are eaten, and tunnels in the fleshy stems above ground are present when the infestation is severe.

TABLE 3. RELATIVE SUSCEPTIBILITY OF CARROT VARIETIES AND STRAINS TO INJURY BY CARROT RUST FLY

Waltham, Mass., 1929-1932

Variety or Strain	FIRST GENERATION				SECOND GENERATION			
			PERCENT CARROTS (Average)				PERCENT CARROTS (Average)	
	Years Observed	Number Examined	Uninfested	Commercially Damaged	Years Observed	Number Examined	Uninfested	Commercially Damaged
Garden Carrots								
Early Scarlet Dutch Horn	4	300	96.75	1.75	3	250	96.33	2.67
Chantenay	4	429	95.49	3.31	4	350	96.25	2.25
Oxheart	4	310	95.25	3.50	3	250	97.67	2.00
Danvers Half Long	4	300	92.50	6.75	4	350	94.00	5.00
Hutchinson	3	350	88.33	10.33	3	300	90.33	8.00
Nantes	4	300	82.25	14.25	3	250	95.00	4.33
Henderson's Intermediate	2	200	74.50	23.00	2	200	94.00	6.00
*Henderson's Coreless	1	100	96.00	4.00	1	100	95.00	5.00
*Tendersweet	1	50	94.00	2.00	1	50	96.00	4.00
*Table Gem	1	50	98.00	0.00	1	50	88.00	10.00
*Bagley Danvers	1	50	94.00	0.00	1	50	92.00	8.00
*Pride of Denmark	1	50	98.00	0.00	1	50	98.00	2.00
Stock Carrots								
Long Orange Belgian	3	250	88.33	11.33	4	344	91.00	8.75
White Belgian	3	210	81.26	14.63	3	250	88.67	9.00
White Mastodon	2	200	81.00	16.00	2	164	84.16	15.06

*Grown only 1 year when field infestation was very light and results do not indicate true susceptibility.

In these experiments the damage to carrots and other host plants has been classified as follows:

None.— No evidence of feeding by the maggot.

Slight.— Some feeding on the surface of the fleshy root or on the hair rootlets, not enough to make the vegetable unmarketable.

Moderate.— Tip injury which stunts the root, one or two small tunnels in the fleshy root, or badly misshapen roots due to attack when small, although the vegetable may have a small market value when mature.

Severe.— Extensive surface feeding and scars, three or more tunnels in fleshy root, rotted or badly discolored areas due to infestation when small, and otherwise unmarketable because of damage by the carrot rust fly.

Commercially Damaged.— Those vegetables showing either moderate or severe injury.

LOCATION OF LARVAE AND TUNNELS IN CARROTS

In October 1928, carrots which were heavily infested with rust fly larvae were examined and the location of the larvae recorded. In the larger carrots, which averaged 8 inches in length, the maggots were quite evenly distributed from the

TABLE 4. LOCATION OF LARVAE AND TUNNELS IN CARROTS

Second Generation, Waltham, Mass. 1928.

LOCATION	LARGE CARROTS			SMALL CARROTS (Bulbous and Misshapen)		
	Number of Larvae	Percent of Total Larvae	Average Number of Larvae per Inch	Number of Larvae	Percent of Total Larvae	Average Number of Larvae per Inch
1st inch.....	9	4.74	0.36	9	10.00	0.36
2nd inch....	23	12.11	0.92	30	33.33	1.20
3rd inch.....	20	10.53	0.80	33	36.67	1.50
4th inch.....	32	16.84	1.28	14	15.56	1.17
5th inch.....	26	13.68	1.04	4	4.44	4.00
6th inch.....	27	14.21	1.08			
7th inch.....	26	13.68	1.08			
8th inch.....	21	11.05	1.17			
9th inch.....	6	3.16	0.55			
10th inch.....	0	0.00	0.00			

	Large Carrots	Small Carrots
Variety..................	Hutchinson	Chantenay
Number examined.........	25	25
Length — Maximum......	10 inches	5 inches
Minimum.......	6 inches	2 inches
Average........	8 inches	3.3 inches
Rust Fly Larvae		
Total number.........	190	90
Number per carrot		
Maximum........	17	13
Minimum........	3	0
Average..........	7.6	3.6

second to the eighth inch with the greatest number being found in the fourth inch. In short carrots, which were 2 to 5 inches long, averaging 3.3 inches, and were also misshapen by earlier attacks of the rust fly (Plate 2), 70 percent of the maggots were found in the second and third inches.

TYPE OF PLANTS ATTACKED

When young carrots develop tops 2 inches high and a root about ¼ inch in diameter, they attract the flies for oviposition.

After the carrots become mature or well grown and are exposed to the attack of the second generation flies, the greatest injury is most likely to be found on the better and more normal carrots (Plate 4). In two separate plantings in 1928, severe injury by the second generation of the carrot rust fly was found in 81 and 83 percent of the large, well-shaped carrots; while in other plantings, in which practically all of the carrots were stunted and misshapen by the attack of the first generation maggots, only 34 and 48 percent were moderately or severely damaged by second generation larvae. There was plenty of food in the smaller, stunted carrots (Plate 4) for a much larger number of larvae, and it was apparent that the flies distinguished between the quality of the carrots when laying eggs.

SEASONAL ABUNDANCE

The field infestation of the carrot rust fly varied each season, and, in order to determine the abundance of these insects and the potential infestation, soil from sections of beds where carrots were grown the previous season was examined each spring.

Samples 1 foot square and 6 inches deep were taken from the garden, both where carrots were left in the ground over winter and where carrots were harvested in the previous fall. Each sample was placed in a tub of water and the soil thoroughly stirred and washed until the lumps were broken. When the pupae were freed from the soil, they immediately floated to the surface of the water where they were collected and counted. Immersion did not harm the pupae, and many of those washed out in this way were used in the life-history studies.

The result of these collections is given in Table 5, which shows that the overwintering population in 1929 was approximately twice as large as in 1930, and ten times as large as in 1931 and 1932. Table 5 also shows that if the carrots are

TABLE 5. NUMBER OF OVERWINTERING CARROT RUST FLY PUPAE IN 1 SQUARE FOOT OF SOIL 6 INCHES DEEP

Waltham, Mass. 1929–1932.

YEAR	INFESTED CARROTS LEFT IN SOIL OVER WINTER			INFESTED CARROTS PULLED IN FALL		
	Number of Samples	Number of Pupae Recovered	Average Number of Pupae per Square Foot	Number of Samples	Number of Pupae Recovered	Average Number of Pupae per Square Foot
1929	5	395*	79.00	5	16**	3.3
1930	16	622	38.87	5	4	8.0
1931	25	204	8.16	10	1	0.1
1932	43	347	8.07	10	1	0.1

*Carrots left in soil had a 74 percent infestation in 1928.
**Carrots pulled had a 54 percent infestation in 1928.

harvested at the normal time in the fall and taken from the field, the number of rust flies which survive is reduced to a minimum. In 1929, when 74 percent of the carrots left in the field over winter were infested, 79 rust fly pupae per square foot of soil were found the following spring; but only 3.3 pupae per square foot were found where heavily infested carrots were harvested. In the four years when records were obtained, the number of pupae found where carrots were left in the ground was 25 to 80 times more than where the carrots were harvested.

DESCRIPTION[1]

Egg

White, oblong, about four times as long as broad, length varying from 0.6 mm. to 1 mm., marked longitudinally by narrow ridges and furrows. Furrows between ridges with circular pits so that sculpture resembles the surface of a peanut shell. Constricted at one end, forming a knob or pedicel which is about one-third as wide as the widest part of the egg. (See Plate 1.)

Larva

Length 6 to 9 mm., width 1 to 2 mm. When newly hatched, it is generally colorless with white opaque spots, later becoming creamy white in color and gradually darkening until, when full grown, it is a dark straw-yellow. The head is sharply pointed and bears two prominent black hooks for gnawing. The rear end is blunt and obliquely docked and bears the dark-colored caudal spiracles.

Pupa

Length 4.5 to 5 mm., width 1 to 1.25 mm., but varying considerably in size. Bright amber brown in color, compact, and prominently obliquely docked behind. When the adult emerges, this docked portion acts as a lid, opening at the posterior tip and usually remaining hinged at the forward edge.

Flies

Length 4.5 to 5 mm. Males slightly smaller than females. Wings thin, slightly iridescent, and extending nearly half their length beyond the abdomen. Abdomen and thorax shiny, black, sparsely clothed with short yellowish hairs. Head and legs pale yellowish brown. Eyes black. Basal joint of antenna same color as head, but terminal joint black or tipped with black. Abdomen of male rounded at apex; of female, sharply pointed at apex.

LIFE HISTORY, SEASONAL HISTORY, AND HABITS

HIBERNATION

The carrot rust fly hibernates in a puparium in the soil within a few inches of the plant in which the larva developed. In the field most of the puparia are 4 to 6 inches beneath the surface, although a few have been found deeper.

In the fall of 1927 about a bushel of infested carrots was placed in a sunken screen cage containing 10 inches of soil, and the larvae were permitted to enter the soil naturally. The following April the soil in this cage was carefully removed in layers 2 inches deep and thoroughly examined. Of the 170 pupae recovered, 85.88 percent were in the top 6 inches of soil, being distributed as shown in Table 6.

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[1] Adapted from Harvey, Maine Agr. Expt. Sta. Ann. Rpt. for 1893:178, with changes based on study of specimens reared and collected at Waltham.

Table 6. Depth in soil at which carrot rust fly hibernates

Waltham, Mass. 1927–1928.

Depth of Soil Inches	Number of Pupae Recovered	Percent of Total
0 to 2	4	2.35
2 to 4	38	22.35
4 to 6	104	61.18
6 to 8	18	10.59
8 to 10	6	3.53

OVERWINTERING GENERATION

Pupation takes place within 4 or 5 days after the maggots become full grown and enter the soil, and this may occur between September 1 and the time when the soil freezes.

Emergence of Flies

The flies of the overwintering generation emerge about the time that early carrots are 2 to 4 inches long. This varies with the season, and at Waltham the period of principal emergence has been from May 20 to June 13. As shown in Table 7 the earliest emerging fly was found on May 16, 1930, and the latest on July 10, 1928.

Table 7. Emergence of carrot rust flies —overwintering generation

Waltham, Mass. 1928–1932.

Year	Number of Flies	DATE OF EMERGENCE First	 Maximum Number	 Last	Period of Principal Emergence	
1928	349	May 29	June 7	July 10	May 31–June 13	(74.21%)
1929	329	May 24	May 29	June 28	May 27–June 1	(55.72%)
1930	721	May 16	May 22	June 24	May 20–24	(39.66%)
1932	347	May 20	May 25	June 28	May 24–27	(32.56%)

The emergence of the flies is influenced by temperature, and in 1930 approximately two and one-half times as many flies emerged on days when the average temperature was 60° F. or lower as when it was above 60° F., as shown in Table 8.

Further indications that relatively low temperatures are more favorable to the emergence of the carrot rust flies were obtained in 1932 when 25 field-collected pupae were placed in each of four constant-temperature cabinets about 6 weeks before the normal emergence period. As shown in Table 9, more than 80 percent of the pupae transformed at 55° to 65° F. while none transformed at 85° F. These records show that the flies appear earlier at the higher temperatures but that few of them survive.

TABLE 8. RELATION OF TEMPERATURE TO EMERGENCE OF CARROT RUST FLY IN INSECTARY

Waltham Mass. May 16–June 22, 1930.

Average Daily Temperature	Number of Days	Average Number of Flies Emerged Per Day	
46–50° F.	3	32.7	32.1
51–55° F.	7	17.6	
56–60° F.	4	46.0	
61–65° F.	5	17.0	12.8
66–70° F.	8	16.5	
71–75° F.	6	10.7	
76–80° F.	5	7.0	

TABLE 9. EMERGENCE OF CARROT RUST FLY AT CONSTANT TEMPERATURES

Waltham, Mass. 1931–1932.

Temperature	Percent of Flies Emerged	Average Date of Emergence	
		1931	1932
55° F.	84	May 21	May 31
65° F.	88	May 22	May 19
75° F.	44	May 18	May 15
85° F.	0	———	———

A slightly or moderately moist soil is most favorable to emergence. Observations on 400 pupae in 1929 showed that the emergence from dry soil was 33 percent, from slightly moist soil 80 percent, and from wet soil 54 percent. In a similar experiment in 1931, using 10 pupae in each cage, soil moistened to 25 percent saturation was most favorable. In these studies the soil moisture was controlled by adding sufficient water to maintain a predetermined weight of moist soil in the cages.

TABLE 10. INFLUENCE OF SOIL MOISTURE ON EMERGENCE OF CARROT RUST FLY AT CONSTANT TEMPERATURES

Waltham, Mass. 1931.

Soil Saturation	Percent Flies Emerged At —				Total
	55°	65°	75°	85°	
100%	00.0	10.0	00.0	00.0	2.5
75%	80.0	70.0	00.0	00.0	37.5
50%	80.0	70.0	80.0	00.0	57.5
25%	90.0	100.0	90.0	00.0	70.0
Total	62.5	62.5	42.5	00.0	41.87

Proportion of Sexes

Records of 259 flies of the overwintering generation in 1929 showed 57.5 percent of them to be females and 42.5 percent males; and in four different emergence cages the proportion of the female flies was slightly greater. Male flies are more abundant early in the season, and in the first 5 days of the emergence period in 1929, 75.86 percent of the flies were males.

Length of Life of Flies

Under insectary conditions, either in battery jar cages or under lantern globes over potted carrots, flies were very short-lived. In 1928, 1 fly lived 11 days and the average life for 20 flies was 4.3 days. Female flies lived a fraction of a day longer than male flies. Under experimental conditions the life of the flies was considerably longer at cooler temperatures, and they lived from 7.3 to 6.6 days longer at 55° F. than at 85° F., as shown in Table 11.

TABLE 11. LENGTH OF LIFE OF CARROT RUST FLIES AT CONSTANT TEMPERATURES

First Generation. Waltham, Mass.

Constant Temperature	Average Length of Life, Days	
	1928	1932
55° F.	11.1	9.2
65° F.	7.5	5.0
75° F.	4.4	3.5
85° F.	3.8	2.6
Insectary, average 70° F.	2.5	3.9

FIRST GENERATION

Oviposition

The eggs of the carrot rust fly are laid singly although as many as 10 have been found together in a group. They are placed in crevices in the soil and among the pellets of earth, or occasionally on the crown of the carrot if it extends above the surface of the ground. When first laid, the eggs are usually partially exposed; but in a short time the movement of the soil particles by wind or cultivation, and the washing by rain or irrigation, may cover them slightly. Newly laid eggs have never been found more than 2 inches away from the carrots, and cultivation close to the plants or the disturbance of the soil during thinning or weeding provides favorable conditions for oviposition.

In the insectary studies, female flies have laid 35 eggs during their short life, but this number is considerably above the average, which was 6 eggs in 1928 and 18 eggs per female in 1929.

Under normal conditions eggs are laid one or two days after the flies emerge, and oviposition continues during the life of the flies, with the greatest number of eggs being laid on the third day after emergence. In normal seasons the egg-laying period begins the last of May and extends for about a month. Seasonal conditions cause some variation in this activity, as shown in Table 12.

TABLE 12. PERIOD OF OVIPOSITION OF THE CARROT RUST FLY

First Generation, Waltham, Mass. 1928–1930.

Year	Number of Eggs	DATE EGGS LAID First	Maximum Number	Last	Period of Greatest Oviposition
1928	700	June 11	June 27	July 9	June 25–30
1929	1126	May 24	May 28	June 4	May 27–June 1
1930	2737	May 18	June 2	June 21	June 11–14

When flies were confined in lantern globe cages at constant temperatures, it was apparent that temperatures below 70° F. were much more favorable than higher ones.

TABLE 13. RELATION OF CONSTANT TEMPERATURE TO THE LIFE AND OVIPOSITION OF THE CARROT RUST FLY

First Generation, Waltham, Mass. 1931.

Constant Temperature	Average life of the Flies in Days	Average Number of Eggs Per Fly	Reproduction Ratio*
55° F.	11.1	10.7	118.77
65° F.	7.5	18.6	139.50
75° F.	4.4	4.8	21.12
85° F.	3.8	5.1	19.38

*Reproduction ratio is determined by multiplying the average length of life by the average number of eggs laid.

Incubation of Eggs

In the insectary studies, the eggs were placed on damp blotting paper in shallow covered glass dishes or on blocks of plaster of Paris set on moist sand, and under these conditions from 55 to 95 percent of the eggs hatched. As shown in Table 14, the period of incubation ranged from 3 to 17 days, and averaged 6.17 to 9.70 days.

TABLE 14. INCUBATION PERIOD OF THE CARROT RUST FLY EGGS

First Generation, Waltham, Mass. 1928–1930.

Year	Number of Larvae Hatched	INCUBATION PERIOD, DAYS Maximum	Minimum	Average
1928	410	11	4	6.17
1929	399	17	5	9.70
1930	1492	14	3	7.17

The length of the incubation period and the number of larvae which hatch are dependent upon temperature. This was first indicated in 1930 when 20 eggs placed in the greenhouse where the temperature ranged from 70° to 105° F. failed to hatch; but when 20 eggs were placed in a root cellar where the temperature was 60° to 70° F., maggots hatched from all of them in 12 and 13 days. In 1932, eggs were placed in constant-temperature cabinets operated at 55°, 65°, 75°, and 85° F. In these cabinets all of the eggs died at 85° F., and the 65° F. temperature appeared most favorable.

Table 15. Incubation of carrot rust fly eggs at constant temperature

First Generation, Waltham, Mass. 1932.

Constant Temperature	Number of Eggs Observed	Larvae Hatched Percent	Average Incubation Period Days
55° F.	31	93.93	20.1
65° F.	38	95.10	9.05
75° F.	48	87.27	6.10
85° F.	40	0.00	——

Feeding of Larvae

The time required for the feeding and development of the larvae in the carrots was approximately 4 weeks, the average period in the three years when studies were made varying from 27.5 to 30.1 days. This feeding period of the first generation larvae generally occurs from the middle of June to the middle of July, but it may begin June 1 and extend to August 1.

When the maggots have completed their growth in the carrot, they enter the soil within 1 or 2 inches of the root in which they were feeding and form a small cell about 4 inches beneath the surface.

During the first 3 days in the soil the maggots make preparations for the pupal period. In 1928 the time in the soil averaged 30.8 days, but in 1930 this period was 41.44 days. In 1930 there appeared to be two groups, one of which spent 7 weeks in the soil while the other spent about 4 weeks in the soil. Although there is no definite proof regarding the cause of this variation, it is apparently connected with drought or temperature and indicates the ability of these pupae to survive unfavorable conditions.

Table 16. Feeding of carrot rust fly larvae in carrots

First Generation, Waltham, Mass. 1928–1930.

	NUMBER OF DAYS LARVAE FEEDING		
Year	Maximum	Minimum	Average
1928	33	15	27.55
1929	39	29	30.1
1930	36	23	29.08

Emergence of Flies

Although the first flies of the first generation have appeared as early as July 21, the majority of them are present between August 1 and 20, and they may continue to emerge until the first week in September. In 1928, 75 percent of the flies emerged August 9 to 18, and in 1929, 85 percent of them emerged August 19 to 24. In the breeding cages these flies lived 4 to 5 days, or approximately the same length of time as the spring emerging flies.

The average time required for the development of the carrot rust fly from the laying of the eggs to emergence of the flies has been 9 to 11 weeks, as shown in Table 17. Some individuals have not completed their life cycle for 110 days, and others have developed in 44 days.

TABLE 17. SUMMARY OF THE LIFE HISTORY OF THE CARROT RUST FLY

Waltham, Mass. 1928–1930.

	AVERAGE NUMBER OF DAYS				
	1st Generation			2nd Generation	
	1928	1929	1930	1928	1930
Incubation of Eggs..........	6.17	9.70	7.17	6.32	6.12
Feeding of Larvae...........	27.55	30.1	29.08	——	27.25
Prepupae and Pupae in Soil ..	30.8	——	41.44	——	——

SECOND GENERATION

Eggs of the second generation are laid during the month of August and their abundance is considerably affected by climatic conditions. Hot, dry weather and general drought apparently reduce the number of eggs laid and also the survival of those which are laid. Even in the insectary where the cages were shaded and moistened each day, this generation of flies laid only about one-third as many eggs as the overwintering spring generation flies.

The average incubation period of the eggs of the second generation was 6.32 days in 1928 and 6.12 days in 1930, being approximately the same as the time required for the incubation of eggs of the first generation. (See Table 17.)

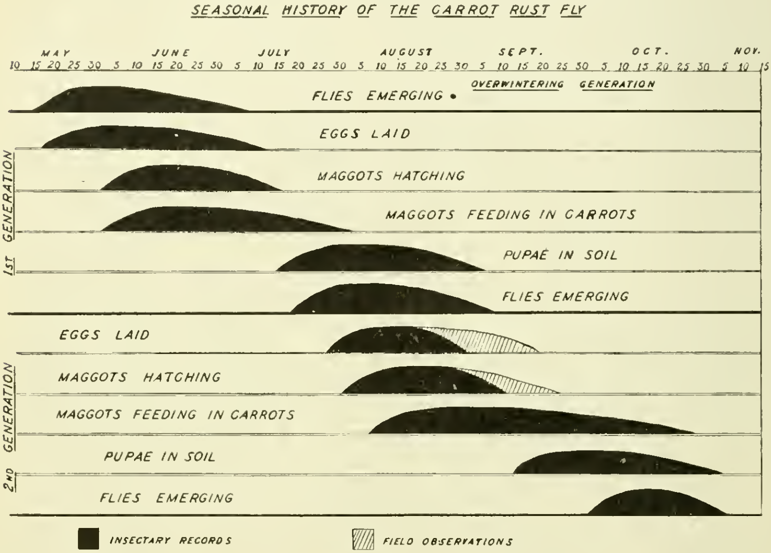
Most of the larvae hatch and enter the roots in August, but they may continue to attack the carrots into October. As with the first generation, the feeding period is about 4 weeks, averaging 27.25 days in 1930. The majority of the maggots which enter the carrots after September 1 remain in them after they are dug and stored, and may cause considerable damage to the carrots in storage where they continue to feed at temperatures above freezing. If the carrots remain in the soil, maggots may continue feeding in them until the ground freezes, and in some seasons the larvae do not complete their development and enter the soil to pupate until well into winter. In 1930 a larva reared in the insectary entered the soil to pupate on November 5 after being partially exposed to freezing temperatures several times.

In both 1929 and 1930, a few second generation flies were reared in October, but, although they were handled by the usual insectary methods and lived for several days, they failed to lay eggs.

THIRD GENERATION

No third generation development has been studied in the insectary. However, from the examination of carrots pulled in October, it was evident that many of the small, partly grown maggots were probably hatched from third generation eggs, and it is the writer's opinion that a third generation of maggots develops in this locality in some seasons. Glasgow (17) also reports a partial third generation in New York State.

Figure 1



CONTROL

CULTURAL PRACTICES

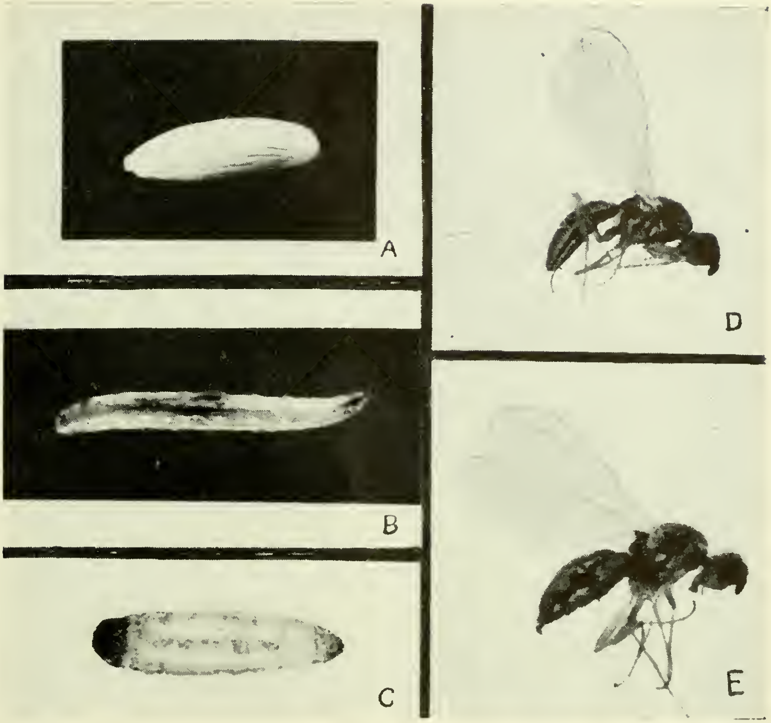
Throughout the study of the life history and habits of the carrot rust fly it has been apparent that the activity of this insect is limited by its environment and that hot weather and dry soil are unfavorable to its development and reproduction. Cultural practices can, therefore, be manipulated so as to provide less favorable conditions for the insect and reduce the degree of infestation and damage.

Legend for Plate 1

Life Stages of the Carrot Rust Fly.
A--Egg ×45) B--Larva or Maggot ×7)
C--Pupa ×7) D--Adult Fly, Male ×7)
E--Adult Fly, Female ×7.

Typical Injury by the Carrot Rust Fly.
LEFT--On Carrot; RIGHT--On Celery.

Plate 1



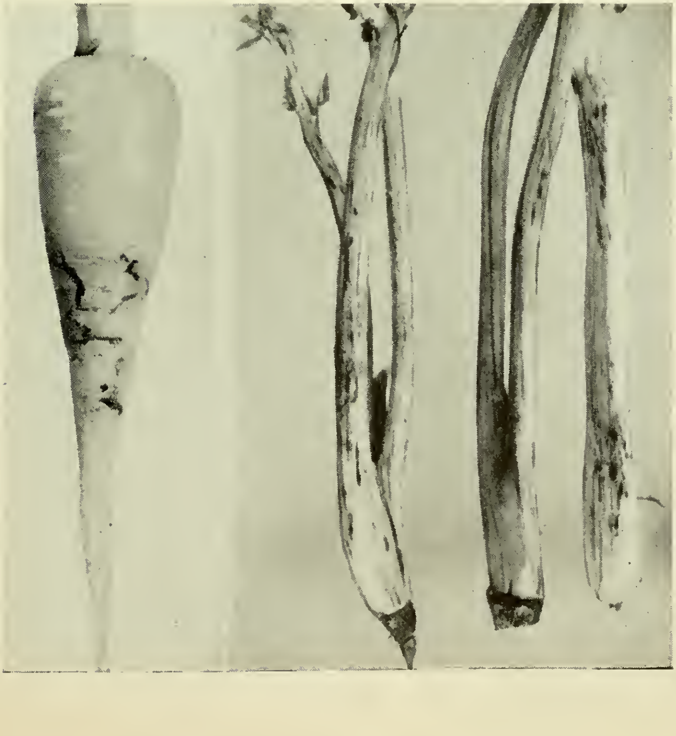
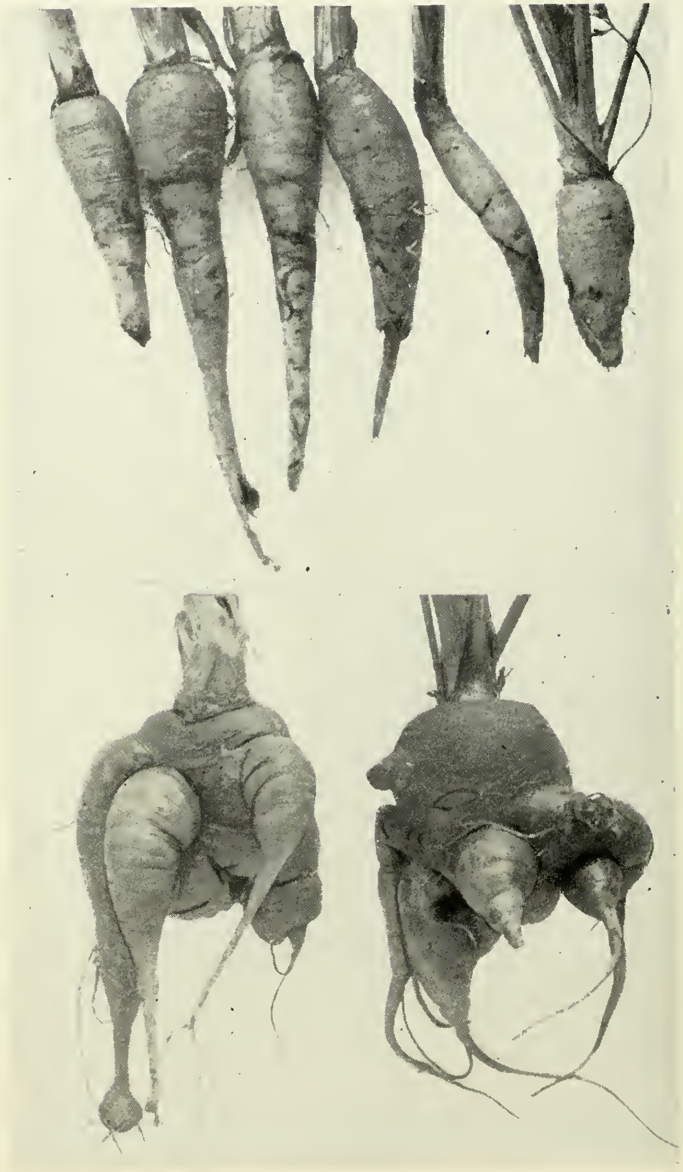


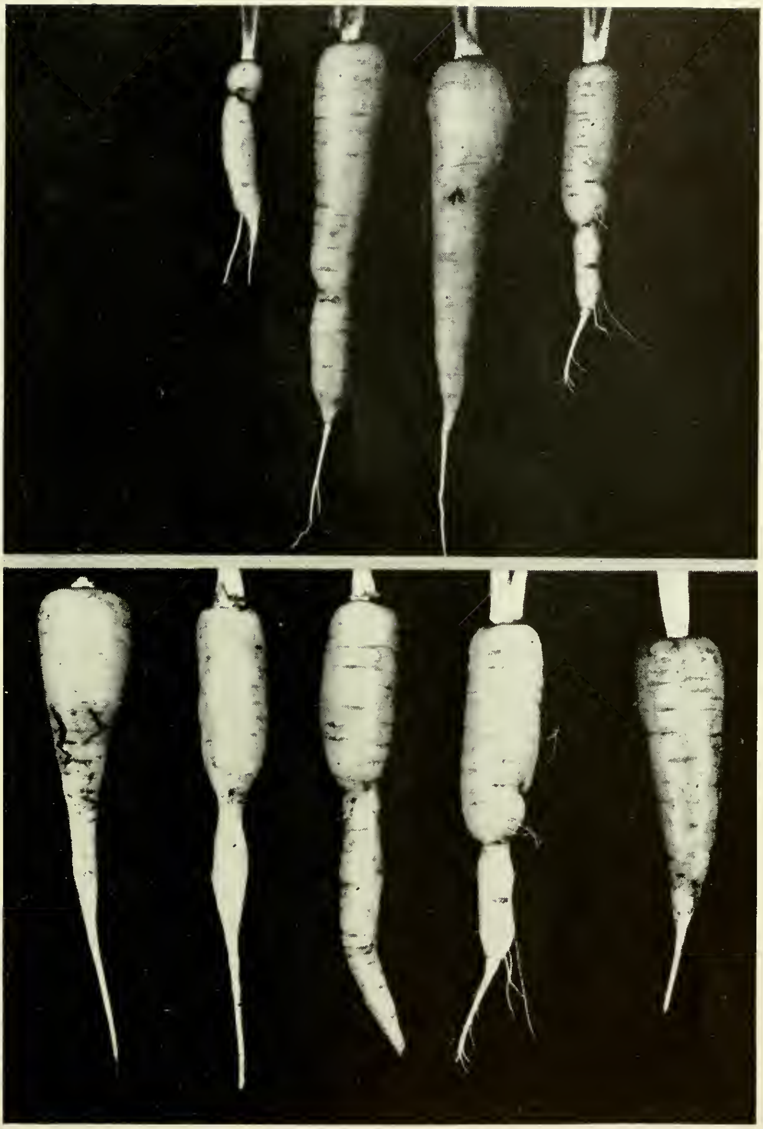
Plate 2



UPPER--Young Carrots Severely Damaged by Larvae of Carrot Rust Fly. The Growing Tips are Completely Destroyed.

LOWER--Deformed Carrots: The Result of Such Severe Injury as Shown Above.

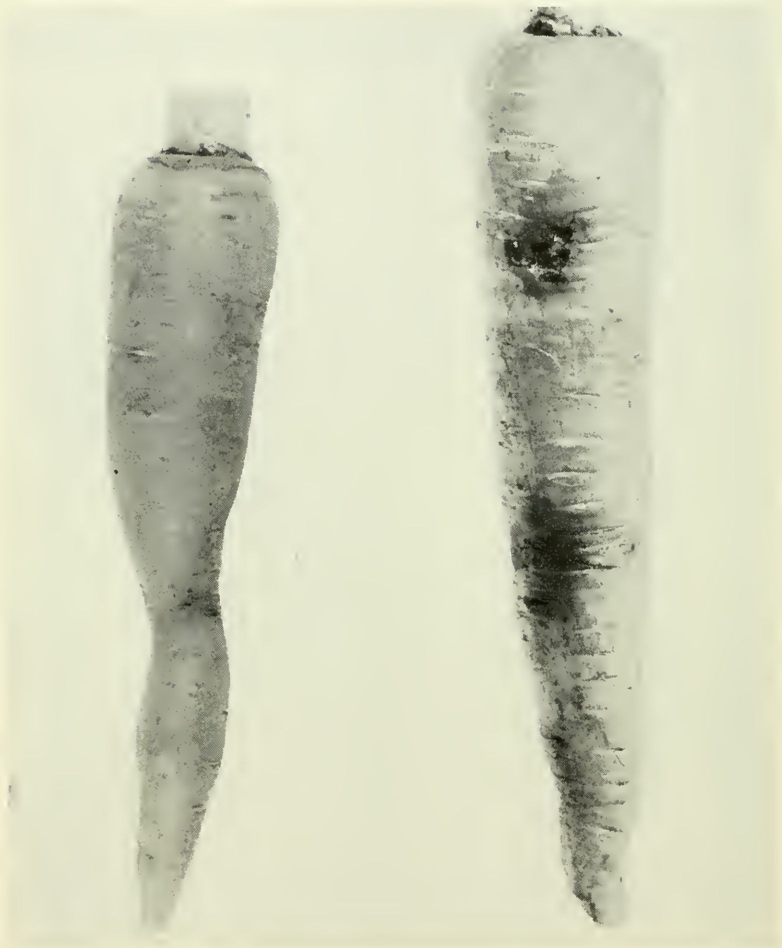
Plate 3



Types of Injury to Young Carrots by Larvae of the Carrot Rust Fly.

Note the bulbous appearance of some carrots where they have resumed growth after being stunted by injury.

Plate 4



Appearance of Injury by Larvae of the Carrot Rust Fly on Mature Carrots.

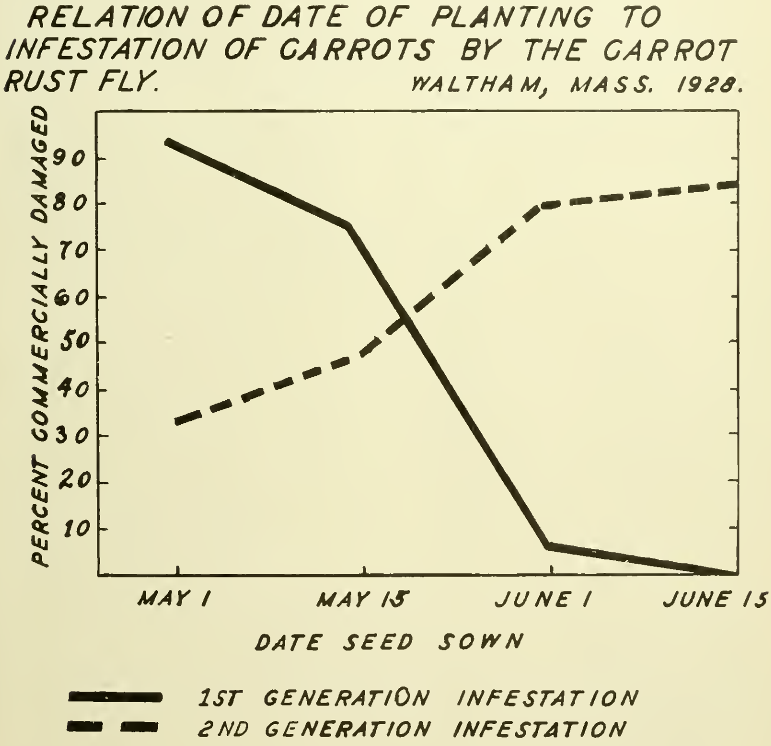
LEFT--Discolored area showing exit holes of larvae; outer skin of carrot still covering the tunnels.

RIGHT--Blotchy scar from which outer skin of carrot has been eaten or decayed, exposing tunneled area beneath.

Date of Planting

The most important of these cultural practices is to grow the carrots at a time when they will be least subject to attack by the carrot rust fly. Nearly every reference states that damage from this pest can be avoided or decreased by planting the seed after the period of attack of the first generation, and harvesting the crop before the period of attack of the second generation. Carrots generally develop to marketable size in 68 to 80 days from seed, depending upon the variety; but plantings at Waltham required a somewhat longer growing period.

Figure 2



In Figure 2, which summarizes the results in 1928 during a heavy infestation, the effect of planting at different dates is brought out very clearly. In this planting every carrot examined from the May 1 planting was infested by larvae of the first generation, while none of the carrots planted June 15 had been infested when examined on July 28. In this year, the growing season was late and the first planting was not possible until May 1. In 1929 and 1930, however, the season permitted plantings on April 1 and 15, and although the infestation was lighter in these years, the April plantings were more heavily infested than the later plantings. It is, therefore, apparent that the earlier the carrots are planted the more likely they are to be infested by the first generation of the carrot rust fly. This is explained by the fact that the larger seedlings during the oviposition period of the flies are more attractive for egg laying, and that cool, damp weather, which is favorable for development, is more likely to occur.

Injury by the second generation has never been so definitely connected with the date of planting as that by the first generation, but there is considerable evidence to indicate that the later the carrot seed is planted the more likely there is to be injury by the second generation larvae. This was especially noticeable in the 1928 plantings when over 80 percent of the carrots planted in June were commercially damaged (Figure 2). Records of second generation injury have been taken from the middle of September to the first of October. At that time early-planted carrots are old and hard, and it is apparent that the more tender growth of late-planted carrots is more attractive to the flies.

Table 18 summarizes the records of planting dates at Waltham from 1928 to 1932. Because of variable degrees of infestation during these years, the results are not so consistent as in Figure 2 but the general trend is quite evident.

TABLE 18. EFFECT OF DATE OF PLANTING ON INFESTATION OF CARROTS BY CARROT RUST FLY

Waltham, Mass. 1928-1932.

Variety	Date Sown	FIRST GENERATION INFESTATION			SECOND GENERATION INFESTATION		
		Number of Years Observed	Number of Carrots Examined	Percentage of Carrots Commercially Damaged	Number of Years Observed	Number of Carrots Examined	Percentage of Carrots Commercially Damaged
Chantenay	April 1	2	595	34.33	1	100	1.00
	April 15	4	500	3.75	1	100	4.00
	May 1	5	750	20.08	2	350	18.70
	May 15	5	750	14.96	2	350	33.70
	June 1	1	250	8.40	1	250	81.20
	June 15	1	250	0.00	1	250	83.20
Hutchinson	April 1	2	600	25.30	1	100	1.00
	April 15	2	300	13.75	1	100	4.00
	May 1	2	300	9.00	1	100	8.00
	May 15	2	300	0.00	1	100	38.00
	June 1				4	400	23.50
	June 15				4	400	14.00

Soil Moisture

Infestations have been noticeably greater in cool, moist locations than in warm, dry exposures. Since 1930, when the infestations have been light, the majority of the infested carrots have been found only in the lowest parts of the field where the soil has been moist and cool.

TABLE 19. EFFECT OF IRRIGATION ON THE CARROT RUST FLY

Waltham, Mass. 1931–1932.

	PERCENTAGE OF CARROTS INFESTED	
	Irrigated	Not Irrigated
First Generation		
1931	2.00	None
1933	3.00	None
Second Generation		
1931	17.00	4.00
1933	25.00	19.00

In 1931 and 1933 the effect of moisture was demonstrated in plantings in which a portion of the carrots was kept wet during the oviposition period of both the first and second generation flies by means of an overhead irrigation system. Although the field infestation was extremely light, the greater number of infested carrots was found in the irrigated part of the planting as shown in Table 19.

Mulch Paper

From 1928 to 1931 considerable interest was shown in the stimulating effect on the growth of vegetables of paper used as a mulch (14). The paper used for this purpose was impervious and coated with asphalt which gave off an odor distinctly repellent to insects.

In these experiments with carrots the seed was sown in rows 14 inches apart, and mulch paper 12 inches wide was laid between the rows, leaving a 2-inch strip uncovered along the row. In most of these plantings the paper was laid when the carrots had grown about an inch high, or, at least, when they had grown sufficiently to mark the rows distinctly; but in a few of the plantings the paper was laid at the time the seed was sown. In 1928 several rows of carrot seed were sown on November 23 and paper was laid between the rows about May 1, 1929.

TABLE 20. EFFECT OF MULCH PAPER ON INFESTATION BY THE CARROT RUST FLY

Waltham, Mass. 1928–1931.

Year	Variety	Seed Sown	PERCENTAGE OF CARROTS COMMERCIALLY DAMAGED			
			First Generation Infestation		Second Generation Infestation	
			With Mulch Paper	Without Mulch Paper	With Mulch Paper	Without Mulch Paper
1928	Chantenay	May 15	10.00	60.00		
1928	Danvers Half Long	May 15			46.80	9.60
1928	Danvers Half Long	June 15			83.20	90.00
1929	Bagley Danvers	Nov. 23, 1928	37.00	89.00		
1929	Chantenay	Nov. 23, 1928	9.00	33.00		
1929	Chantenay	May 13	0.00	1.00	9.00	2.00
1929	Hutchinson	June 15			16.00	11.00
1930	Chantenay	April 15	2.00	3.00		
1931	Chantenay	April 15	0.00	0.00	7.00	4.00

As shown in Table 20, the mulch paper gave considerable protection from first generation injury, especially in 1928 and 1929, but there was more injury by the second generation where the paper was used. Apparently, the repellent odor of the asphalt provided the protection against the first generation of the flies, but the odor had disappeared by August 1 when the flies of the second generation were ovipositing, and instead of repelling the flies the paper actually provided a protected, favorable location in which to lay eggs. A comparison of carrots grown with and without paper is shown in Table 21.

Mulch paper is too expensive and its use too difficult to be practical in commercial carrot plantings, but it may be satisfactory in the home garden where the cost and labor are less important.

In connection with the studies of mulch paper as a repellent to the carrot rust fly, observations made on the stimulation to growth by this paper showed a gain of 20 to 33 percent in the weight of carrots grown under paper; but this advantage does not seem enough to offset the cost and labor involved in using it.

Table 21. Response of carrots to mulch paper stimulation

Waltham, Mass. 1930–1931.

	Weight of fifty carrots								Percentage gain in weight	
	With Mulch Paper				Without Mulch Paper					
	1930		1931		1930		1931		1930	1931
	Lb.	Oz.	Lb.	Oz.	Lb.	Oz.	Lb.	Oz.		
With tops......	15	6	14	12	12	4½	11	6	20.3	22.9
Without tops...	8	6	8	8	6	11	5	10	20.1	33.8

Repellent Effect of Onions

Early in these studies it was suggested that the odor of onion might have a repellent action against the carrot rust fly, and from 1929 to 1933 onions and carrots were planted in alternate rows. The rows were 14 inches apart and there were at least four rows of onions and three rows of carrots in each planting.

As shown in Table 22, damage by the carrot rust fly of the first or second generation, or both, was slightly less where the carrots were interplanted with onions than where the carrots were grown in solid blocks. However, the practice did not seem to give sufficiently positive protection for reliable results and is recommended only where the two crops can be grown together without inconvenience to the other farm practices.

Table 22. Repellent effect of onions on the carrot rust fly when interplanted with carrots

Waltham, Mass. 1929–1933.

Year	Seed Sown	Variety		Number of carrots examined		Percentage commercially damaged	
		Carrot	Onion	With Onions	Without Onions	With Onions	Without Onions
			First Generation				
1929	May 1	Danvers Half Long	Danvers Yellow Globe	200	115	8.5	40.00
1930	May 1	Hutchinson	Danvers Yellow Globe	100	100	0.0	1.00
1930	May 1*	Danvers Half Long	Danvers Yellow Globe	100	100	2.0	4.00
1931		Chantenay	White Southport	150	50	5.0	13.28
			Second Generation				
1930	June 10	Hutchinson	Danvers Yellow Globe	200	100	8.0	14.0
1931	June 10	Hutchinson	Danvers Yellow Globe	200	100	2.5	2.0
1932	June 10	Hutchinson	Prizetaker	100	100	5.0	7.0
1933	June 10	Hutchinson	Prizetaker	100	100	7.0	19.0

*At Danvers.

Rotation

Since the known host plants of the carrot rust fly are few in number and the only important vegetables in this list are carrots, celery, parsnips, and parsley, the cropping plan of the vegetables can be adjusted to avoid heavy infestations of this pest. The operation of a market garden with none of these crops might be difficult, but this should not be necessary except in emergencies following a year of extremely severe and widespread damage by the carrot rust fly. Naturally, the planting of the same crop or one of the other host crops on the same land year after year would encourage the continuance of rust fly infestations and should be avoided

Carrot rust flies are comparatively strong fliers and apparently are able to locate host plants at a considerable distance from their point of emergence. Under such conditions, however, the infestation is seldom severe, especially on early host crops. At Waltham in 1928 carrots planted approximately 300 yards from previously infested plantings showed 32 percent commercial injury, while those grown on land having heavily infested carrots the previous season showed 74.8 percent commercial injury.

Rotation of these crops is a commendable practice from the standpoint of disease prevention and general culture; and if infestation by the carrot rust fly is suspected, carrots, celery, or parsnips should be planted as far from the planting of the previous season as practical.

Carrots and celery are frequently grown as both early and late crops. Two crops in a season provide ideal conditions for both the first and second generations of the rust fly, and less injury from this insect will result if these crops are grown only in early plantings or only in late plantings. It is better to omit the early plantings and thus prevent the first generation of the pest from finding suitable breeding quarters in which to build up a strong second generation. In Massachusetts, late crops can be grown from seed planted June 15, and this will completely avoid the flies of the first generation.

As noted in the "Date of Planting" studies, little or no injury by first generation rust fly occurs when the seed is sown June 1 or later, and by planting an early maturing variety (65 to 70 days) satisfactory bunching carrots can usually be grown between the periods of attack by the first and second generation of this pest.

Harvesting

Infested carrots should be pulled completely and thoroughly, including all the stunted and otherwise worthless roots. The value of this is well shown in Table 5, where it is reported that the number of carrot rust fly pupae recovered in the spring was from 26 to 80 times larger where infested carrots remained in the ground over winter than where infested carrots were carefully pulled and taken from the field.

Although the maggots and pupae of the carrot rust fly are less affected by cultivation than are many insects, the movement of the soil crushes, buries, and exposes enough of them to make fall plowing a recommended practice for infested plantings.

Storage

Carrots infested with the rust fly maggots should never be stored, because these maggots are able to continue their feeding and growth at ordinary storage temperature. Even after careful grading, it has been found that many carrots which were apparently in good condition when placed in storage were worthless when removed, because of feeding by the rust fly maggots which had not been discovered during the grading.

The writer has not considered the fumigation of carrots infested with rust fly maggots to be practical under general conditions; but if it is advisable for any reason, the use of carbon disulfide at the rate of 4 ounces for each 100 cubic feet for 18 hours is recommended.

A small experiment with fumigants, which is summarized in Table 23, was made in October 1930, using 25 carrots having an approximate equal infestation in each of the treatments. The carrots were fumigated in iron barrels having a capacity of 3½ cubic feet. No injury to the carrots was observed and the odor of the chemicals disappeared quickly with airing.

TABLE 23. EFFECT OF FUMIGATION ON CARROTS INFESTED WITH CARROT RUST FLY LARVAE

Waltham, Mass. October, 1930.

Material	Rate	Exposure Hours	Number of Living Maggots Found
Calcium cyanide	1 lb.–1,000 cu. ft.	18	1
Paradichlorobenzene	12 oz.–100 cu. ft.	42	0
Carbon disulfide	4 oz.–100 cu. ft.	18	0
None			21

Infested carrots which have been brought in from the field should be treated so that the maggots are killed. This can be done by putting them into silage, feeding to stock immediately, or storing for later disposal in an absolutely tight container which can be washed out later with boiling water or strong disinfectant.

INSECTICIDES

Preliminary experiments in the laboratory showed that the eggs and adults of the carrot rust fly were killed by several of the common insecticides, and the practical use of these materials is primarily a matter of expense and thorough application. With low yields and moderate prices, the use of insecticides to combat the carrot rust fly might be questionable; but where yields of 500 bushels per acre are obtained and in seasons when the infestation is so severe as to place a price premium on uninfested carrots, the application of insecticides should be worth while. In general, however, the writer agrees with Doran and Guba (6) that spraying is seldom practical because "a horse-drawn sprayer naturally cannot be used in such a closely planted crop as carrots," and "a small compressed-air sprayer lacks in both capacity and pressure."

Laboratory Experiments

Eggs

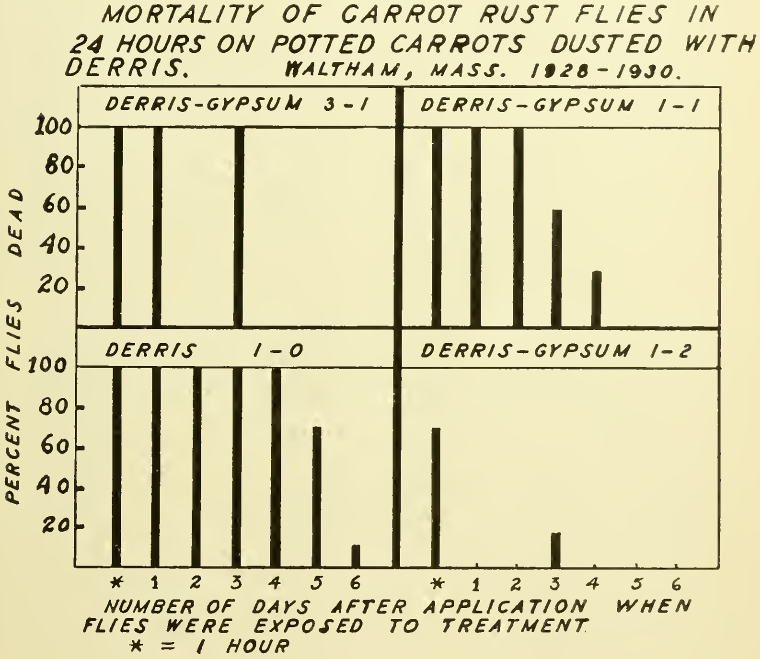
In 1929 carrot rust fly eggs were placed on moist blotting paper in petri dishes and carefully but thoroughly sprayed or dusted. The materials used were corrosive sublimate solution 1-1,000, Derrisol spray 1-250, Bordeaux–oil emulsion 1 percent oil, 4 percent calomel–lime dust, and undiluted ground derris root (5 percent rotenone). No larvae hatched from eggs exposed to any of these treatments, while about 20 percent hatched from the untreated eggs.

Flies

During 1928, 1929, and 1930, about 300 newly emerged carrot rust flies were confined in groups of 10 in lantern globe cages over potted carrots which had been sprayed or dusted with various insecticides. Where dusts were used, the flies were confined with the treated plants immediately (Fig. 3) after application, except in special experiments; but the liquid sprays were allowed to dry on the plants before the flies were caged with them.

In these studies derris killed the flies with unusual speed and consistency, especially as a dust. Corrosive sublimate, sodium fluosilicate, pyrethrum, sulfur, and Bordeaux oil emulsion gave considerable protection to the carrot but did not kill the flies quickly or consistently. Soot, naphthalene, and benzene compounds were repellent but not particularly toxic to the flies. In these cages some of the flies on the untreated carrots lived 8-13 days, and the average life of those on plants with general insecticide treatments was about 7 days. However, when the plants were dusted with derris mixtures no flies lived longer than 2 days.

Figure 3



Another series of tests indicated that undiluted derris dust killed all the flies in 24 hours when they were confined with the plants 4 days after the dust was applied, but that it was only partially effective 5 and 6 days after application. Derris–gypsum dusts containing 75 percent and 50 percent derris killed all the flies 3 days after application, but a dust containing 33 percent derris killed only 70 percent of the flies when they were exposed to it immediately, as is shown diagrammatically in Figure 3.

Seed Treatment with Calomel

Coating the seed with mercury salts has given considerable control of root maggots in onion, cabbage, and cauliflower, as reported by Glasgow (16). Field experiments with carrot seed treated with calomel (mercurous chloride) were made at Waltham from 1929 to 1937. The treatment was applied by placing the seed with one-half its weight of calomel or calomel–clay mixture in a bottle or can and thoroughly shaking until the seed was completely coated. On ordinary

Table 24. Results of field experiments with seed treated with calomel for control of carrot rust fly

Waltham, Mass. 1929-1937.*

Material	FIRST GENERATION INFESTATION				SECOND GENERATION INFESTATION			
	Years Applied†	Number of Carrots Examined	Percentage of Carrots Commercially Damaged‡	Percentage Gain over Check	Years Applied	Number of Carrots Examined	Percentage of Carrots Commercially Damaged‡	Percentage Gain over Check
Calomel (pure)	1929–35–36–37	458	0.93	94.10	1929–30–33–34	400	15.50	48.34
Calomel (pure) (on seed and in drill)	1929	200	1.50	93.19	1929–30	175	12.50	72.53
Calomel–clay 1–1	1937	100	4.00	71.43				
Calomel–clay 1–3	1935–36–37	400	4.50	67.08	1934	100	16.00	—60.00
Calomel–clay 15–85	1935	100	22.00	12.99	1934	100	11.00	—10.00
Calomel–clay 1–9	1935	100	8.00	68.00	1934	100	12.00	—20.00
Calomel–clay 1–24	1935	100	15.00	40.00	1934	100	21.00	—110.00
None (check)	1929	200	22.00		1929	100	52.00	
	1935	100	25.00		1930	100	39.00	
	1936	100	2.00		1933	100	19.00	
	1937	100	14.00		1934	100	10.00	

*In the first generation planting in 1929, Danvers Half Long was grown; in all others, Hutchinson.

†Carrots were grown from treated seed in 1930 and 1934 first generation planting, but no records were obtained because there was no infestation in the check plantings.

‡Where the same treatment was applied in more than one year, the percentages are averaged.

carrot seed one-half pound of calomel will adhere to one pound of seed after shaking together. This should be done just before the seed is placed in the planter for sowing. Results are summarized in Table 24.

Against the First Generation

In the experimental plantings when the seed was coated with pure calomel, the protection against the first generation of the carrot rust fly was consistently good. Even when the natural infestation in the untreated rows was light, ranging between 2 and 25 percent, the infestation in the treated carrots did not reach 2 percent, and represented an average gain of 94 percent in 1929. When calomel was sprinkled in the seed drill as well as on the seed, the infestation was reduced from 25 percent in the check to 1.5 percent; but the use of additional calomel did not seem worth the extra expense on the early carrots. Treatment of the seed with a mixture containing 1 part of calomel and 3 parts of clay did not give consistent protection, being very effective in 1935 but only partially so in 1936 and 1937. Greater dilutions of the calomel were much less effective and unsatisfactory. In 1930, 1932, 1933, and 1934, when treated seed was planted, the infestation in the untreated carrots was either none or so little that results of insecticide treatments were valueless, especially in the early plantings. In 1933, 1934, and 1935, seed was treated with corrosive sublimate–clay mixture containing 15 and 25 percent corrosive sublimate; but this injured the seed and caused very poor germination, being especially injurious in 1934.

Against the Second Generation

Seed treatments against the second generation have been much less effective in these plantings, owing partly to a heavier infestation and partly to the longer period from the time the seed was sown until the carrot was attacked. Where the undiluted calomel was used, the infestation was reduced about 20 percent in three of the four years when it was used. On the late carrots calomel in the drill as well as on the seed was by far the most effective seed treatment, and it is valuable where a heavy infestation is anticipated. For this purpose a pound of calomel for each pound of treated seed (in addition to the calomel on the seed) should be placed in the seeder and allowed to drop out with the seed.

Field Experiments with Contact Insecticides

Conditions and Methods of Application

Studies of insecticides to control the carrot rust fly in the field at Waltham have been greatly handicapped by the tremendous variation in the natural infestation from year to year due to climatic and soil conditions unfavorable to the development and reproduction of the insect. In 1928 when the work was started, field counts showed from 70 to 90 percent moderate and severe injury to untreated carrots. In 1929 this decreased to 22 percent in the early carrots and 52 percent in the late carrots. In 1930, 1932, and 1934, no injured carrots were found in the early plantings, making some extensive insecticide experiments worthless. Between 1930 and 1937 the commercial injury to the check plantings was always less than 20 percent. Under these conditions, it is evident that results of the experiments are applicable only to moderate or light infestations and that the effectiveness of the treatments might be considerably less in heavy infestations.

Throughout the ten years covered in this report, the carrots used for insecticide studies have been grown in blocks of 3 to 9 rows, 14 inches apart and from 60 to 120 feet long.

All dusts were applied with a plunger type duster holding about four pounds of dust. Application was made from one side only, and the dust was directed onto the crown of the carrot and the soil immediately adjacent to it. On small seedlings less than 2 inches high, the dust was usually applied from above and the foliage of the plant was covered, but on the larger plants no attempt was made to cover the tops thoroughly. The insecticidal dusts were used in these experiments at approximately ¼ pound to 100 feet of row or about 75 pounds per acre. More dust was used in the late applications to larger plants, but no comparison of heavy and light dosages was made.

Sprays were applied from compressed-air knapsack sprayers with the nozzle held close to the ground so that the crown of the plant and the adjacent soil was thoroughly wet. Materials for spraying were less expensive than for dusting, but application with the necessary thoroughness was very laborious and impractical on large plantings.

In summarizing the results of treatments which were applied in more than one season, the percentage of carrots injured is averaged for all seasons in which the treatment was used. Likewise, the percentage gain over check is calculated from the average injury to the treated carrots and the average infestation in the untreated carrots for the corresponding years.

Time of Application

Insecticides for combating the carrot rust fly should be applied while the flies are active and eggs are being laid. Based on the life history studies at Waltham, the first insecticide treatments on early carrots have been applied during the last week in May or the first week in June. Because of the variation in spring development from year to year, the emergence period of the flies should be determined; but in the absence of such information, an average date for the first application of insecticides is June 1. Three or four applications at approximately weekly intervals appear to be necessary, and a heavy rain soon after treatment usually necessitates the repetition of the application.

Table 25. Time of application of insecticides and repellents in field experiments for control of carrot rust fly

Waltham, Mass. 1928–1937.

Year	DATE OF APPLICATIONS				
	First	Second	Third	Fourth	Fifth
			First Generation		
1928	June 15 and 16	June 23	June 28–30	July 2	
1929	May 31	June 6	June 14		
1931	May 28	June 3	June 13		
1932	May 27	June 4	June 10		
1934	June 7	June 14	June 21		
1937	June 5	June 12	June 19	June 26	
			Second Generation		
1928	August 20	August 28			
1929	August 12	August 16	August 22	August 28	
1930	July 29	August 5	August 12		
1931	August 4*	August 13 and 14	August 21		
1932	August 5	August 12	August 19	August 27	
1933	July 31	August 7	August 14	September 4	September 12
1934	July 30	Discontinued because of absence of flies			
1935	July 29	August 4 and 5	August 12	August 19	August 28
1936	July 28	August 4	August 11	August 18	August 25

*Extra application August 8.

The first application for late carrots should be made about August 1. The activity of flies of the second generation usually continues throughout the month of August, and consequently four applications at about weekly intervals are advisable. When volatile materials such as naphthalene are used, the applications should be repeated as soon as the crystals have evaporated, and in very warm weather this may occur in less than a week. The dates when insecticides were applied during these studies are shown in Table 25.

Discussion of Materials

With derris, cube, pyrethrum, calomel, fluosilicates, oil emulsions, and nicotine, the flies are killed by contact at the time of application, or by creeping through the insecticide while it is fresh on the plants. To a less extent, also, the flies are repelled and the eggs and newly hatched larvae of the carrot rust fly killed by contact with these materials.

Derris, Cube, and Pyrethrum.— Derris and cube have been the most consistently effective materials, especially to control the first generation flies on early carrots. Good results with derris were also obtained by Gorham (correspondence) in New Brunswick, Canada. Derris and cube, which contain rotenone and other toxic resins, are primarily fish poisons, being relatively nonpoisonous to warm-blooded animals but toxic to insects and other cold-blooded animals.

In the first work with derris, the undiluted derris root was superior to any mixture of it with gypsum. In fact, the greatest commercial damage by the flies where this treatment was used was 13.2 percent in 1928, which represented a gain of 64.4 percent over the check; and the average loss in 3 years was only 7.73 percent as shown in Table 26. However, ground derris root costs at least 40 cents a pound and undiluted it is much too expensive for commercial use on carrots. Since 1933, derris and cube powders have been improved by careful handling and grinding. In 1937, four applications of a cube–clay dust containing 0.6 percent rotenone gave complete protection from a 14 percent infestation in an adjacent check; and in 1932 and 1933 a similar commercial dust containing 0.55 percent rotenone permitted an average damage of only 3.5 percent, which represented the greatest gain from any treatment with a contact insecticide against the second generation. This dust is now readily available for about 13 cents a pound, and used at the rate of 50 to 75 pounds per acre it would cost from $6.50 to $10 for each application. This expense has not been justified in the last few years; but with a heavier infestation and a yield of 500 bushels or more per acre, it might be practical on early carrots. On small plantings and home gardens it can be recommended.

Sprays containing rotenone have been quite effective but in most cases are more difficult to apply.

Pyrethrum as a dust or spray was less effective than derris or cube.

Mercury and Fluosilicates.— Corrosive sublimate solution, prepared by dissolving 1 ounce of corrosive sublimate in 7½ gallons of water, has given moderately good control in experiments, and has been found effective by Caesar (3) in Ontario. However, a stunting of the growth from this treatment is reported by Caesar and has been observed by the writer. At Waltham, this material also caused rough, blotchy areas on the skin of the carrot, which have been referred to as mercury russet.

A spray of calomel (mercurous chloride), 1 ounce in 5 gallons of water, did not stunt the growth of the carrots but failed to control the pest with three applications in 1929. Dusts containing 2 and 4 percent calomel in lime or gypsum gave fair commercial control of light infestations in 1930 and 1933, but did not control a heavier infestation in 1929.

TABLE 26. RESULTS OF FIELD EXPERIMENTS WITH CONTACT INSECTICIDES FOR CONTROL OF CARROT RUST FLY

Waltham, Mass. 1928–1937.

Material		FIRST GENERATION				SECOND GENERATION			
		Years Applied	Number of Applications per Year	Percentage of Carrots Commercially Damaged*	Percentage Gain over Check	Years Applied	Number of Applications per Year	Percentage of Carrots Commercially Damaged*	Percentage Gain over Check
Derris and Pyrethrum Materials									
Derris dust (undiluted)		1928–29–31	3	7.73	78.24	1928	2	79.2	12.00
						1929	4	29.80	42.70
						1930–31	3	8.50	22.73
Derris-gypsum dust	75–25	1928	4	27.2	64.95	1928	2	76.80	14.67
	50–50	1928–29	3	23.15	56.52	1928	2	77.6	13.78
						1929	4	32.16	38.16
	33–67					1930	3	12.00	14.29
Cube-clay dust	0.6% rotenone	1937	4	0.00	100.00				
	(commercial) 0.55% rotenone					1932–33	3	3.50	73.08
Derrisol spray	1–250	1928–29	3	16.60	66.67	1928	2	70.4	21.78
						1929	4	20.0	61.54
	1–500	1928	3	21.6	72.17	1928	2	79.2	12.0
Pyrethrum dust (undiluted)		1928	4	43.6	43.82				
Pyrethrum-gypsum dust 50–50		1928	4	43.6	43.82				
Pyrethrol spray 1–100		1928	3	32.4	58.25				
Red Arrow spray 1–200		1928	3	38.4	50.53				
M. P. spray 1–250		1928	3	44.8	42.27				

Mercury and Fluosilicate Materials								
Corrosive sublimate spray 1–1000	1928–29	3	25.8	48.10	1928	2	52.8	41.34
					1929	4	19.0	63.47
					1930	3	19.0	—35.71
Calomel spray 1 oz. in 5 gals	1929	3	25.5	—15.90	1929	4	53.0	—1.92
Calomel-gypsum dust, 4% calomel	1929	3	25.5	—15.90	1929	4	53.0	—1.92
Calomel-lime dust, 4% calomel					1930	3	6.0	57.15
					1933	5	12.0	36.85
Calomel dust (commercial) 2% colloidal calomel					1930	3	7.0	50.00
					1932	4	6.0	14.29
					1933	5	9.0	52 64
Sodium fluosilicate-gypsum spray 2–2–50	1928	4	26.4	65.98	1928	2	93.2	—3.55
	1929	3	35.5	—61.36				
Sodium fluosilicate-gypsum dust 50-50	1928	3	35.2	54.64				
Calcium fluosilicate dust	1928	3	54 4	29.90				
Miscellaneous Materials								
Lubricating oil emulsion 1%	1928	4	74 0	4.64				
Bordeaux 4–4–50+oil emulsion 1%	1929	3	15.0	31.82	1929	4	44.0	15.39
50% Nicotine sulfate 1–500	1929	3	40 0	—81.81				
None (check)	1928		77.6		1928		90.0	
	1929		22.0		1929		52.0	
	1931		7.0		1930		14.0	
	1937		14.0		1931		8.0	
					1932		7.0	
					1933		19.0	
					1934		10 0	

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*Percentage of carrots commercially damaged is calculated for the average of the years reported.

TABLE 27. RESULTS OF FIELD EXPERIMENTS WITH REPELLENT INSECTICIDES FOR CONTROL OF CARROT RUST FLY

Waltham, Mass. 1928–1936

Material	FIRST GENERATION				SECOND GENERATION			
	Years Applied	Number of Applications per Year	Percentage of Carrots Commercially Damaged	Percentage Gain over Check	Years Applied	Number of Applications per Year	Percentage of Carrots Commercially Damaged	Percentage Gain over Check
Naphthalene flakes	1931	4	1.0	85.72	1933–35–36	5	1.67	82.76
	1931	3	0.0	100.00	1931–35–36	4	2.00	66.67
					1931–35–36	3	1.00	83.33
					1935–36	2	3.00	40.00
					1934–35–36	1	10.33	—15.50
Naphthalene-sulfur 50–50	1929	3	5.0	77.28	1929	4	29.00	44.23
Scotch soot	1929–31	3	2.0	86.21	1929	4	21.00	59.62
					1930–31–34	3	5.67	41.38
					1933	5	6.00	68.43
Ground tobacco (1¼% nicotine)	1931	3	0.00	100.00	1931–32	4	1.50	80.00
					1932	2	5.00	28.57
					1932	3	2.00	71.43
					1933	5	12.00	36.85
Kainit 5 lb.—100 sq. ft.	1931	1*	8.00	—14.28	1933	1*	5.00	73.69
Talc 1 to 2 lb.—60-ft. row	1931	3	2.00	71.43	1931	3	2.00	75.00
Wood ashes 1½ to 2 lb.—60-ft. row	1931	3	2.00	71.43	1931	3	4.00	50.00
Limestone 1¼ to 2 lb.—60-ft. row	1931	3	8.00	—14.28	1931	3	1.00	87.50
None (check)	1928		77.6		1928		90.0	
	1929		22.0		1929		52.0	
	1931		7.0		1930		14.0	
					1931		8.0	
					1932		7.0	
					1933		19.0	
					1934		10.0	
					1935		4.0	
					1936		6.0	

*Applied when seed was sown.

Sodium and calcium fluosilicates in a spray or dust were either ineffective or inconsistent. In fact, with the exception of derris and cube, no insecticidal sprays or dusts were sufficiently outstanding to receive commercial consideration.

Miscellaneous Materials.— Several reports, particularly by Gibson (15) and Pettit (23). have suggested the use of kerosene emulsion or Bordeaux oil emulsion for combating the carrot rust fly. In 1928 and 1929, spraying with a 1 percent lubricating oil emulsion and a 1 percent oil emulsion in Bordeaux mixture 4-4-50 was only slightly effective and did not warrant further applications. A plot sprayed with a solution of nicotine sulfate containing 50 percent nicotine diluted 1-500 showed more injury than the check, even to the point of suggesting that the nicotine may have attracted the flies.

Field Experiments with Repellents

Naphthalene, soot, tobacco, talc, lime, and wood ashes are primarily repellent to the flies. In addition to the repelling effect, naphthalene and tobacco kill the eggs and newly hatched larvae by contact and fumes. Soot, talc, and similar dusts maintain a dry, powdery coating which is very disagreeable to the flies. The repellency of these materials is greatly decreased by wetting.

Of these repellents, naphthalene flakes, Scotch soot, and ground tobacco, in three or four applications on early carrots and three to five applications on late carrots, gave consistently good protection in experiments from 1929 to 1936.

Naphthalene Flakes.— Glasgow (17) in New York found naphthalene flakes the most satisfactory control for carrot rust fly in late carrots when used at the rate of 400 pounds per acre in four to six applications at weekly intervals. In the experiments at Waltham, three or more applications gave about 80 percent protection over a period of 4 years on late carrots, and in 1931 on early carrots (see Table 26). Naphthalene flakes in a crude form cost 4 to 5 cents a pound in barrels holding 100 pounds or more, and 6 to 8 cents a pound in smaller quantities. This material was applied at the rate of 1 pound to each 100 feet of row, or approximately 350 pounds per acre, at an approximate cost of $14 per acre. It was broadcasted by hand, spread along the rows so that the flakes were scattered among the crowns of the carrots. When taken from the bag or barrel the flakes may be in lumps, which should be broken up by kneading and crushing by hand to avoid an uneven distribution. No injury to the foliage or roots of the carrot has resulted from naphthalene, and there has been a slight unexplained stimulation from its use.

In 1929 a mixture of equai parts of sulfur and naphthalene was used, but the mixture appeared slightly inferior to the naphthalene.

Tobacco.— Ground tobacco containing 1 to 1¼ percent nicotine was used in 1931, 1932, and 1933 with generally good results. In 1931, three applications gave perfect protection to early carrots from a very light infestation (7 percent) in an adjacent untreated block. On late carrots two applications were ineffective in 1932, and it appeared that three or more treatments at weekly intervals were necessary. After several trial applications with this tobacco, it was determined that approximately 2 pounds to each 100 feet of row were necessary to give an adequate covering on the crowns of the carrots. Ground tobacco costs $3.75 to $4 per 100 pounds and on this basis the cost of making one application to an acre is about $25. This expense is too great for the average commercial carrot grower, but this material might have a place in the small planting or where above-average yields were produced.

Scotch Soot.— Scotch soot, which is a favorite plant stimulant among British gardeners, was found to be repellent to the carrot rust fly. It was not quite so effective as tobacco or naphthalene, and because of its greater bulk about 4 pounds to each 100 feet of row were required to give a good protective covering. Scotch soot costs about $7 per 100 pounds, largely because it is imported, and at that price it cannot be used economically on carrots. However, there is no apparent reason why local soot would not be just as effective if it were available. In addition to repelling the carrot rust fly, the soot apparently caused a healthier growth of the foliage and roots of the treated carrots.

Miscellaneous.— Among the miscellaneous repellents, talc and wood ashes gave good protection from very light infestations, but it was apparent that their action was entirely mechanical and that they would not be effective on large plantings against a severe infestation. In home gardens where they can be applied very carefully, they offer a cheap material which will give considerable protection against light infestations. Limestone was inconsistent, and kainit applied to the seedbed just before planting injured the germination of the seed severely.

SUMMARY

The carrot rust fly, *Psila rosae* Fab., which is considered the most destructive member of the family *Psilidae*, was originally described from Bessarabia, Rumania, in 1794. It was first found in North America in 1885 at Ottawa, Canada, and in 1893 it was identified at Pittsfield, Maine. It has now been reported from fifteen states, principally in the northeastern and northwestern parts of this country, and has not been found south of Adams and Fulton Counties, Pennsylvania, which is approximately 40° north latitude. This insect was especially abundant in 1928 and 1929 in the eastern United States and in 1936 and 1937 in Washington.

Carrots, parsnips, celery, and parsley are most commonly damaged by this insect, but it has attacked several other plants of the botanical family *Umbelliferae* in Massachusetts. Long varieties of carrots are preferred to short, thick varieties, and at Waltham the white varieties of stock carrots suffered more injury than the long orange varieties.

Damage is caused entirely by the feeding of the larvae on the fleshy roots. In large carrots the larvae may be well distributed between the second and eighth inch, but in short carrots 70 percent of the larvae are found in the second and third inches. When carrot roots are about one fourth inch in diameter they may be attacked by the larvae of the carrot rust fly, and normal, well-grown carrots are more likely to be damaged than stunted, mature carrots.

In 1929, 79 pupae per square foot of soil were found where infested carrots were left over winter, and only 3.3 pupae per square foot where carrots were pulled in the fall. In 1931 and 1932 the natural abundance had decreased to approximately one tenth this number.

The life stages of the insect are illustrated and described briefly.

The carrot rust fly hibernates as a pupa in the soil. The majority of them are within 6 inches of the surface but they may be 10 inches deep. Flies appear about May 25 and more of them emerged on days when the temperature was 60° F. or less than when it was higher. In laboratory studies a temperature of 65° F. and a soil moisture of 25 percent saturation were most favorable for emergence. Female flies are slightly more abundant than males, although there may be a greater proportion of males early in the emergence period. The flies are short-lived, and in confinement lived 9 to 11 days at cool temperatures and 2.6 to 3.8 days at 85° F.

Eggs are laid singly in or on the soil near the plant, and the number per female has varied from a maximum of 35 to an average of 6 to 18. The greatest number of eggs was laid at 55° to 65° F., and the principal oviposition period of flies of the overwintering generation extended in three seasons from May 27 to June 3.

Eggs hatch in 6 to 9 days under normal conditions but required 20 days at 55° F. In constant-temperature studies no larvae hatched from eggs held at 85° F., and 65° and 75° were the most favorable temperatures for incubation of the eggs.

The feeding period of the larvae covers about four weeks, varying from 27.55 days in 1928 to 30.1 days in 1929; and approximately the same length of time is spent in the soil as prepupae and pupae. In 1930 there were indications that unfavorable soil conditions extended their period in the soil to seven weeks. In these studies 75 to 85 percent of the flies of the first generation emerged between August 10 and August 25.

The life cycle is completed in 9 to 11 weeks. The time required for the development of the second generation corresponds very closely with the same period for the first generation. No studies of a third generation have been made, but it is evident that one develops in some seasons.

Cultural practices which provide unfavorable conditions for development and reproduction are important factors in controlling this pest. In Massachusetts seed sown before June 1 will be attacked by the first generation, and seed sown after June 15 is likely to be damaged by the second generation. The growing of host plants on the same area year after year, and the growing of both early and late crops of these host plants near-by in the same season favor the establishment and increase of the carrot rust fly, and these practices should be avoided. Moist soil favors the carrot rust fly, and irrigation at the time the flies were laying eggs increased the infestation. Mulch paper gave good protection on early carrots, but on late carrots it was obviously the cause of a greater infestation by providing protection for the flies during oviposition. Carrots grown with mulch paper were 20 to 33 percent heavier than those grown without paper. Carrots grown in alternate rows with onions were less infested than those grown in solid beds. All infested carrots and parsnips should be pulled, regardless of their value, and treated to kill any insects in them.

Treatment of the seed with one-half its weight of calomel protected early carrots from damage by the first generation of the carrot rust fly, but was not so effective on late carrots against the second generation. Undiluted calomel was more effective than calomel diluted with clay.

In laboratory experiments with insecticides, eggs and adults of this insect were killed by derris sprays and dusts more effectively than with other insecticides. Ground derris root killed all the flies in 24 hours when the flies were caged with dusted plants four days after the dust was applied.

Spraying or dusting carrots for pest control is not generally considered practical or economical in Massachusetts; but where yields of 500 bushels per acre are obtained, or in seasons when severe damage by this insect places a premium on uninfested carrots, insecticides should be worth while. When used, insecticide applications should begin about June 1 on early carrots and about August 1 on late carrots.

In the early experiments, undiluted ground derris root was the most effective insecticide, but this is too expensive for use on carrots. Later, a cube–clay dust containing 0.6 percent rotenone gave good results against a light infestation, and its use is recommended. Mercury compounds and fluosilicate mixtures have not been consistently effective, and Bordeaux–oil emulsion and nicotine were unsatisfactory. Naphthalene, soot, and ground tobacco have been effective as repellents. Naphthalene is preferred when used at the rate of 1 pound to 100 feet of row, and is recommended in three or four applications on late carrots.

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Leaf-Feeding Insects of Shade Trees

By W. B. Becker

Tree Injury by Squirrels

By E. M. Mills

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

LEAF-FEEDING INSECTS OF SHADE TREES

By W. B. Becker, Research Assistant in Entomology[1]

Introduction

The purpose of this bulletin is to make available to the people of Massachusetts information regarding the habits and control of the more important insect pests defoliating the broad-leaved, deciduous shade and forest trees in the Commonwealth. The insects discussed are the ones commonly encountered and, in addition, a few species which have not been reported from Massachusetts but are close to its borders. An account of injury caused by red spiders, or mites, is also included, as well as of the various types of damage caused by squirrels but sometimes mistaken for insect work.

The life histories are subject to some variation from year to year depending on the seasonal climatic conditions.

As far as possible, technical terms and expressions have been avoided. However, because the common name given to the insects often varies with the locality, the scientific name is also given for reference purposes. Some of the terms dealing with the various life stages, transformations, and structures of the insects are included. Briefly, these are as follows:

Life History of Insects. Moths, butterflies, sawflies, and beetles pass through four distinct life stages: egg, larva, pupa, and adult. The egg hatches into a wormlike creature known as a larva. Larvae of moths and butterflies are commonly referred to as caterpillars; the legless larvae of certain moths as slug caterpillars; sawfly larvae as false caterpillars; and beetle larvae as grubs. A larva grows by shedding its skin several times, each time producing a new skin larger than the previous one — a process commonly called molting. After molting a few times, a larva becomes full grown, or mature, and transforms into a pupa. This is a resting stage during which the larval form is destroyed and the adult form developed. The transformation may occur inside a covering — a cocoon for sawflies and moths, a chrysalid for butterflies, a pupal cell for beetles; or it may occur in the absence of a covering, when the pupa is often referred to as being naked. When the transformation is complete, the moth, butterfly, sawfly, or beetle appears. The adult is entirely different in form from the larva so that these insects are said to have a complete metamorphosis. After mating, the female deposits her eggs and the life cycle is repeated.

The development of walkingsticks and spider-mites differs from the above in that the young, called nymphs, have the general form and appearance of the adults. They also go through the process of molting. After each succeeding molt the nymph more closely resembles the adult until it transforms to the adult stage directly without first passing through a pupal, or resting, stage. These are said to have an incomplete metamorphosis.

Structure of an Insect. The body of an insect is divided into three parts: head, thorax, and abdomen. To the head are attached the antennae, or feelers, the eyes, and mouth parts. Directly behind the head is the thorax, to which are attached the wings and true legs. The posterior section is the abdomen. Moths, sawflies, and beetles have two pairs of wings. In the beetles the forewings are hardened and are called elytra. These fold over the hind wings and cover most of the abdomen. The larvae of many moths, butterflies, and sawflies bear on the under side of the abdomen appendages which serve for support and are called prolegs.

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The Abundance of Insects. The common expression, "There are many more insects now than there were in grandfather's day," is true. There have always been insect outbreaks, however. Frequently insect pests native to a region become abundant, cause considerable damage for perhaps a few years, and then become scarce. These outbreaks, followed by periods of scarcity, are due largely to climatic conditions but also to the natural enemies of the insect. When an insect pest is abundant, the enemies which attack it also become abundant and finally increase to such numbers that most of the host insects are killed off. When the insect pest is almost wiped out, many of its enemies starve to death, allowing the few remaining host insects to increase in numbers and again assume epidemic proportions before its enemies can multiply sufficiently to bring it under control.

To this local cycle, man through his travel and transportation activities has accidentally introduced from other parts of the world many pests which were not accompanied by their native enemies. When such an introduced species finds a favorable climate in the new locality and no natural enemies to keep it under control, it spreads unmolested and becomes a much worse pest in the new locality than many of the native pests and often becomes more destructive than it was in its old habitat. For this reason various governments collect predatory and parasitic enemies of an insect pest in the original habitat of that species and introduce them into the new locality with the hope that eventually these enemies will bring the pest under control.

Man has also brought about conditions favorable to more serious insect outbreaks through his tendency to produce pure stands of certain species of trees, that is, areas containing but one species of tree. Many of these stands are the result of direct seeding or planting or are pure stands coming in naturally after clear cutting or fires in the original forest. In many cases the original forests contained mixtures of several species of trees so that many injurious insects which fed on one or only a few species experienced some difficulty in finding their desired food. With the increase in pure stands, these insects had much easier access to a decidedly larger food supply where they could build up much larger populations than before. The fact that insects are prolific breeders aggravated this condition.

Because of the increase in damage caused by insects and the importance of some of our shade and forest trees, it is only natural that artificial means should be used to protect them from attack whenever insect pests become abundant. Protection against leaf-feeding insects is very desirable since defoliation of a tree weakens it and thus makes it more susceptible to attack by bark and wood-boring insects as well as by organisms which do not usually attack healthy trees but which will hasten the death of weakened trees. Leaf-feeding insects alone may kill a thrifty, broad-leaved deciduous tree by completely defoliating it for three years in succession. One complete defoliation may kill a needle-bearing evergreen.

Insecticides. The usual method of controlling leaf-chewing insects which feed on the surface of the leaves is to apply a thorough coating of a poison to the leaves so that the insects must either eat the poisoned leaves, go without food, or look elsewhere for it. For those insects which feed on both sides of the leaves, devouring the entire leaf surface, a poison application on either surface will suffice. If, however, the insect feeds on the tissues of only one surface (e. g., the lower, as is the case with grubs of the elm leaf beetle), then care must be taken to direct the spray to that side of the leaves. Dry, powdered lead arsenate is the chief poison used. Because weathering action is apt to wash this material off the foliage in a short time, flour or calcium caseinate may be added to the liquid spray to make it spread better and stick to the foliage longer. Spreaders also tend to reduce the danger of arsenical injury to the tender foliage of susceptible plants. On especially tender foliage it may be advisable to reduce the amount of lead arsenate. Sometimes raw linseed oil or fish oil is used as a sticker for lead arsenate. These oils, however, have little value as spreaders; neither will they lessen the burning action of the lead arsenate. The fish oil, moreover, is objectionable for use near dwellings because of its unpleasant odor. If soap or sprays containing soap are used with lead arsenate, injury to the foliage may result. After a spray has been applied, the spray tank should be carefully cleaned before another spray is prepared.

The usual method of controlling leaf miners, or insects which feed in the tissues between the surfaces of the leaves, is to apply a contact spray that will kill the insects in the leaves without harming the leaf tissue itself. For this purpose nicotine sulfate, with or without soap, or some similar material is usually applied. Best results are obtained when the insect is young and the leaf mine is small. Later the larvae are more resistant to the spray. The thickness of the leaf tissue also influences the effectiveness of the spray.

In the discussion of the various insects, recommendations for dilution are made for large amounts of spray. The accompanying dilution table gives amounts of the various materials for small quantities of spray of equal concentrations.

Dilution Table for Use of Insecticides

Avoirdupois Weight

Large Quantities	Small Quantities
1 pound in 100 gallons	1/6 ounce in 1 gallon
2 pounds in 100 gallons	1/3 ounce in 1 gallon
3 pounds in 100 gallons	1/2 ounce in 1 gallon
5 pounds in 100 gallons	4/5 ounce in 1 gallon

Liquid Measure

3/4 pint in 100 gallons	1 teaspoonful in 1 gallon
1 pint in 100 gallons	1 1/4 teaspoonfuls in 1 gallon
1 1/4 pints in 100 gallons	1 1/2 teaspoonfuls in 1 gallon
1 1/3 pints in 100 gallons	1 2/3 teaspoonfuls in 1 gallon
1 1/2 pints in 100 gallons	1 9/10 teaspoonfuls in 1 gallon
1 3/5 pints in 100 gallons	2 teaspoonfuls in 1 gallon
1 quart in 100 gallons	2 1/2 teaspoonfuls in 1 gallon

Sprays must be applied when the particular stage of the insect to be controlled is present; otherwise effective results cannot be expected. The experienced operator is fully aware of the importance of this fact but very often the layman is not. The actual date of application, however, may change from year to year, varying with the earliness or lateness of the season. Insect pests are very often not noticed until the damage is almost completed, when it is too late for control measures to do any good. If a pest is known to be present, preparations should be made to control it either in a succeeding generation or in the following season, depending on the species involved and the locality.

Thoroughness in applying a spray is very important. This requires a spray outfit with sufficient power to drive the spray to all parts of the tree. Long lines of hose necessitate higher pressure at the spray tank to supply the necessary drive at the nozzle. To insure thorough and proper coverage requires skill on the part of the operator. Any foliage left unsprayed on a tree is subject to attack and may support a sufficient number of insects to cause serious injury to the whole tree after the spray has weathered off. Unfortunately, even with the best equipment and the most skillful application of the proper materials, unfavorable weather may prevent proper coverage or lessen the value of the spray by rapidly washing it off.

Precautions in the Use of Insecticides. Extreme care should be used in handling poisonous spray materials. They should not be inhaled, swallowed, or allowed to get into open wounds. All equipment used should be thoroughly cleaned and any unused poison should be properly labeled and stored where it is not accessible to human beings or domestic animals.

When using spreaders and stickers with poison sprays to prolong their effectiveness, it should be remembered that these materials will also cause the spray to remain longer on grass or other vegetation and objects under sprayed trees. Children should not be allowed to play beneath recently sprayed trees nor should cattle or other animals graze there.

Certain sprays will stain painted and finished surfaces. To avoid injury of this type such surfaces should be sprayed with water just before, during if possible, and immediately after the spray application. If the spray is applied when the wind is not blowing toward such objects and due care is exercised in spraying, much of the trouble can be avoided. Small objects may be covered. Automobiles should be removed. In California, street spraying for the elm leaf beetle has been carried on at night to avoid traffic problems present during the day. In addition, this procedure speeded up the work and thus reduced expenses.

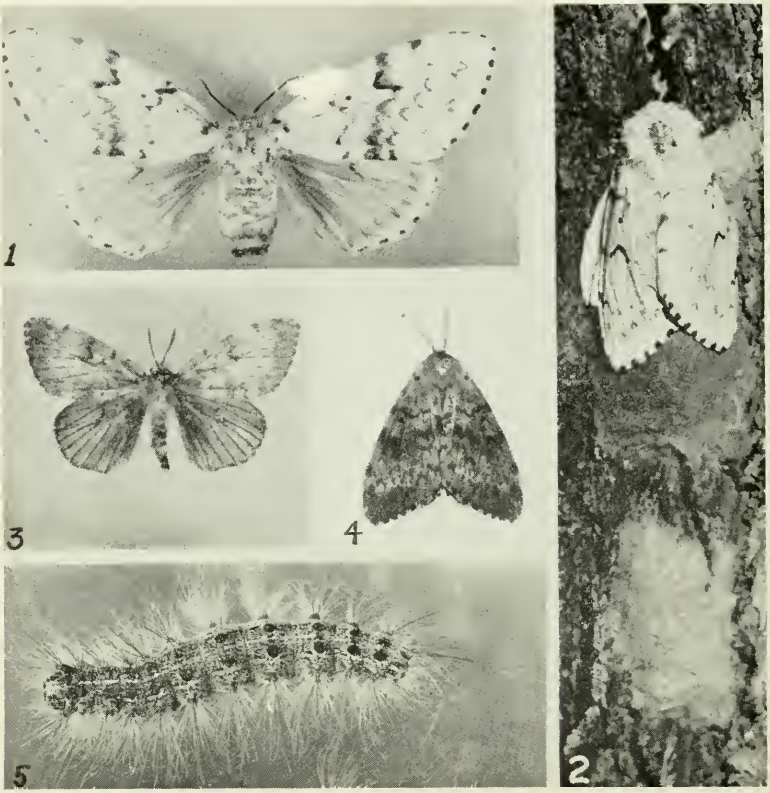
Tree banding materials should be removed at the end of the season to prevent girdling.

Gypsy Moth

Porthetria dispar Linn.

The gypsy moth is one of the most destructive insect pests ever introduced into New England. It is a native of Europe and was brought into this country about 1869 by a person living near Boston, Massachusetts, in connection with experiments in silk culture. Some of the caterpillars escaped from the cages in which they were confined, and from them has come the infestation which has been the cause of so much damage to the woods and shade trees of New England. The federal and state governments have already spent millions of dollars in combating it.

The caterpillars have quite definite food preferences. Some trees are highly favored by all stages, others are less favored; some are attacked only when more desirable food is not available, and some are never attacked. The young caterpillars of the first two stages cannot feed on coniferous trees, with the exception of larch and blue spruce, but must have access to broad-leaved deciduous trees. The older caterpillars, however, may attack and defoliate pine, hemlock, and other coniferous evergreens. Usually only one complete defoliation is necessary to cause the death of a coniferous evergreen; whereas most thrifty deciduous hardwoods require more than one complete defoliation to cause death. Three complete annual defoliations are sufficient to kill many hardwoods.



Gypsy Moth

1. Female moth. Wings spread. Actual size.
2. Female moth. Wings folded, laying eggs on the bark of a tree. Actual size.
3. Male moth. Wings spread. Actual size.
4. Male moth. Wings folded. Actual size.
5. Mature caterpillar. Actual size.

Figs. 1, 3, and 5, Courtesy, Conn. Agr. Expt. Station.

Following is a list of the common forest trees of New England classified according to their preference by the gypsy moth caterpillars, with a discussion of the likelihood of the various mixtures of trees being attacked, as given by Behre, Cline, and Baker.

(1) Species highly favored by larvae in all stages —
- oak (all species)
- alder
- gray birch
- basswood
- willow
- river birch
- poplar (all species)
- box elder
- hawthorn
- apple

(2) Species favored in all larval stages, but distinctly less so than those under 1 —
- paper birch
- larch (all species)

(3) Species edible in all larval stages, but not favored (usually ignored in the presence of species under 1 and 2) —
- maple (all species)
- yellow birch
- black birch
- elm
- sassafras
- hickory (all species)
- black gum
- hornbeam
- black cherry

(4) Species definitely unfavorable in early larval stages but highly favored by larger caterpillars —

- pine (all species)
- hemlock
- southern white cedar
- beech
- spruce (all eastern species)

(5) Species not favored in any larval stage —

- ash
- locust
- tulip tree
- butternut
- red cedar
- black walnut
- dogwood
- American holly
- balsam
- sycamore

Stands composed entirely of species in class 1 may be completely defoliated. Stands of species in class 2 may also be infested, but the likelihood of complete defoliation is distinctly less than in pure stands of class 1 trees. Stands restricted to the species in class 3 are at times lightly infested, but cases of heavy defoliation are extremely rare. Infestation cannot originate in stands composed entirely of species in class 4, and stands restricted to the species in class 5 are practically immune.

Mixtures of classes 1 and 2 are highly susceptible to heavy defoliation. Mixtures of 1 and 3 are highly susceptible only when the proportion of foliage in class 1 is high enough to allow a large number of larvae to enter the later stage of development in a vigorous condition. In such mixtures trees in class 1 are usually entirely defoliated before those in class 3 are severely attacked. In mixtures of classes 1 and 4 the defoliation of the latter is also dependent upon the proportion of class 1 trees present. If sufficient class 1 foliage is available for the larvae to reach the third stage of development in a healthy condition, trees in class 4 may be severely attacked. Mixtures of classes 2, 3, 4, and 5 are seldom defoliated, although the likelihood is greater than in mixtures of 3, 4, and 5.

Gypsy Moth Egg Masses and Empty Cocoons on the Trunk of a Tree.

Description. The wings of the female moth are white, with inconspicuous dark markings. The abdomen is large and covered with brown hairs. The males are smaller than the females and their wings are brown with darker markings. The abdomen is slender.

The eggs are laid in clusters which are roughly oval in shape, from about ½ inch to over 2 inches in length, and contain about 400 eggs on the average. The individual eggs are globular, almost white, and about 1/25 inch in diameter. They are embedded in and covered with fine brown hairs from the body of the female moth.

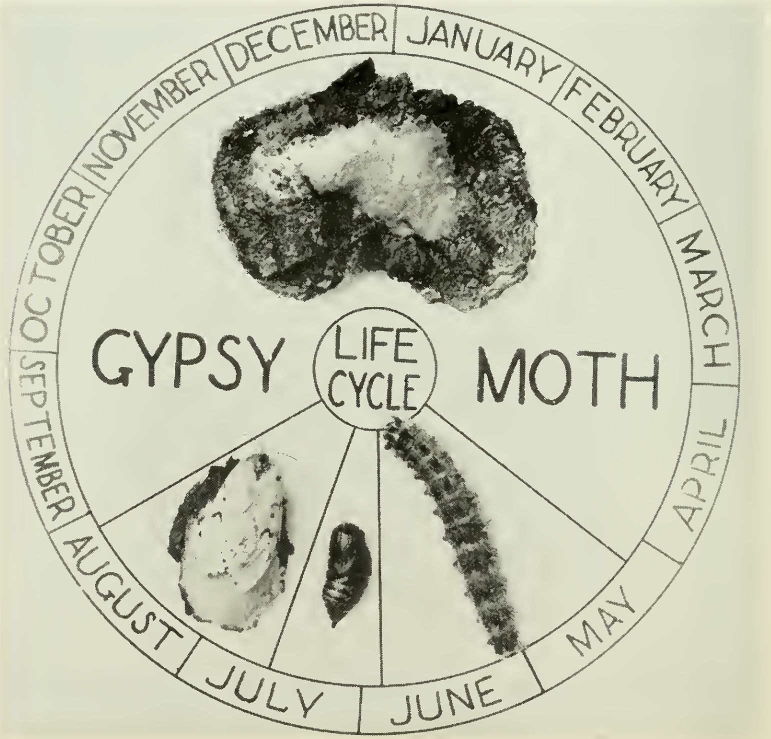


Diagram Illustrating the Life Cycle of the Gypsy Moth.

The larvae, or caterpillars, grow to be about 3 inches long. The body varies in color from brown to gray and is covered with numerous tiny, dark spots which give the caterpillar a mosaic appearance. Running lengthwise along the back there is usually a white stripe, on each side of which on each body segment there is a tubercle. The first five pairs of tubercles are blue; the last six, red. These and other tubercles on the sides bear tufts of long hairs. The head has yellow and brown markings.

The pupae are chestnut brown in color, possess but a few light brown hairs, and are loosely wrapped in a few strands of silk.

Life History. Most of the eggs are laid during July or early August on the trunks and branches of trees, where they may be found on the open bark surface, in crevices and cavities, and under loose bark; or on stone walls, fences, and buildings. The eggs usually hatch the following spring about the time the leaves unfold.

The caterpillars feed mainly at night and usually seek shelter from the sun during the day. When disturbed, the young caterpillars drop on a silken thread and may be blown by the wind for considerable distances. The larvae molt five or six times, become full grown in late June or early July, and seek out a sheltered place in which to spin their cocoons and pupate. The pupal stage lasts from 10 days to 2 weeks, after which the adults emerge. The female moths are heavy bodied and practically flightless so that they usually lay their eggs in the vicinity of the place where they pupated. The male moths are more slender bodied, are strong fliers, and may be found at some distance from areas where the caterpillars fed and pupated.

Control. This insect is being combated in several ways. First, a barrier zone about 30 miles wide has been established at the western limits of the infestation to prevent the pest from spreading beyond its present limits, and all outbreaks found within this area are sought out and eradicated. The zone extends from the Canadian border to Long Island Sound through western New England and east of the Hudson River in New York. In Massachusetts it includes all of Berkshire County and parts of Franklin, Hampden, and Hampshire Counties west of the Connecticut River. In addition to eradication work in the barrier zone, all isolated infestations which originated from independent sources are being cleaned up as rapidly as possible. Second, quarantines have been established to prevent any stages of the insect from being carried out of the heavily infested area, which in Massachusetts at the present time extends close to the eastern border of Berkshire County. Third, control measures are being applied to the insect outbreaks in the infested areas, as follows:

1. Scouting for egg masses and painting them with creosote. A little lampblack is mixed with the creosote so that the treated masses may be distinguished from the untreated. Because of the better visibility when the leaves are not on the trees, this work is done to best advantage in the fall, winter, and early spring; but if snow is present the egg masses covered by the snow will be overlooked. They will also be protected from extremely low temperatures so that a larger percentage will survive the winter under the snow than above the snow line.

2. Spraying foliage in the spring when the leaves become large enough to retain the poison. The spray should be mixed in the proportion of 5 pounds of lead arsenate to 100 gallons of water, with 1¼ pints of raw linseed oil or fish oil added as a sticker. For severe infestations both creosoting and spraying have been found to be essential for satisfactory control.

3. Banding the trees.

a. With burlap during the larval period. A burlap strip about 8 inches wide should be wrapped around the trunk, held in place by a cord tied in the center, and the upper half of the band folded down over the lower. During the day the caterpillars seek shelter beneath this burlap. At frequent intervals the strip should be examined and all caterpillars under it crushed. Wherever brown-tail moths are present this method should not be used until after all the brown-tail moth caterpillars have pupated because these caterpillars may crawl under the burlap and, since they are covered with brittle, poisonous hairs, may cause severe irritation to the hands of the workers who examine the strips.

b. With sticky bands, as described under cankerworms. These bands should be applied just before the caterpillars hatch. Frequent attention during the time the caterpillars are present is necessary to keep the bands in good condition and to kill the caterpillars below the bands. Here again it must be mentioned that the young gypsy moth caterpillars may be carried by the wind. When there is danger that an infestation may be established on a hilltop or other exposed situation from which young caterpillars might be blown easily to other areas, this method of tree banding is employed to protect trees in such locations from migrating larvae. Applying sticky bands to the trunks of coniferous trees around the edge of a pure stand, may also prove a helpful practice.

4. Selective thinning. Because of the food preferences of the caterpillars severe defoliation may be prevented by the removal of those deciduous hardwoods which are preferred by the caterpillars. The number to be removed, of course, depends upon the abundance of the preferred species and the size of the trees. Serious defoliation is not likely to occur in stands of mixed hardwoods where the volume of preferred foliage is less than one half of the total in the stand and is evenly distributed. Stands of coniferous evergreens require a smaller proportion of preferred foliage for the same degree of protection, and it may be necessary to cut a barrier zone about 100 feet wide around them, in which all preferred trees are removed, in order to protect the conifers from migrating caterpillars. In some cases where conditions are especially favorable for an increase of the insect, the presence of even small amounts of preferred foliage may be dangerous.

This practice of removing the trees preferred by the caterpillars, when used in conjunction, with the control measures previously mentioned, should prove valuable to owners of some types of woodlands which are in great danger of being destroyed by this insect. If it is not feasible to apply artificial measures of control, this practice of thinning alone might prove of considerable value. The work, however, should be done only by or under the direction of a person who is acquainted with the feeding habits of the insect and understands the principles of silviculture. In regions where practically the only trees present are those highly favored by the caterpillars, this method of combating the gypsy moth would not be applicable.

Natural control. Many species of insects, both native and introduced, which parasitize or prey upon various stages of the gypsy moth have been studied and liberated in large numbers. These have been successful in reducing severe infestations. During bad outbreaks of the caterpillars a wilt disease often kills large numbers.

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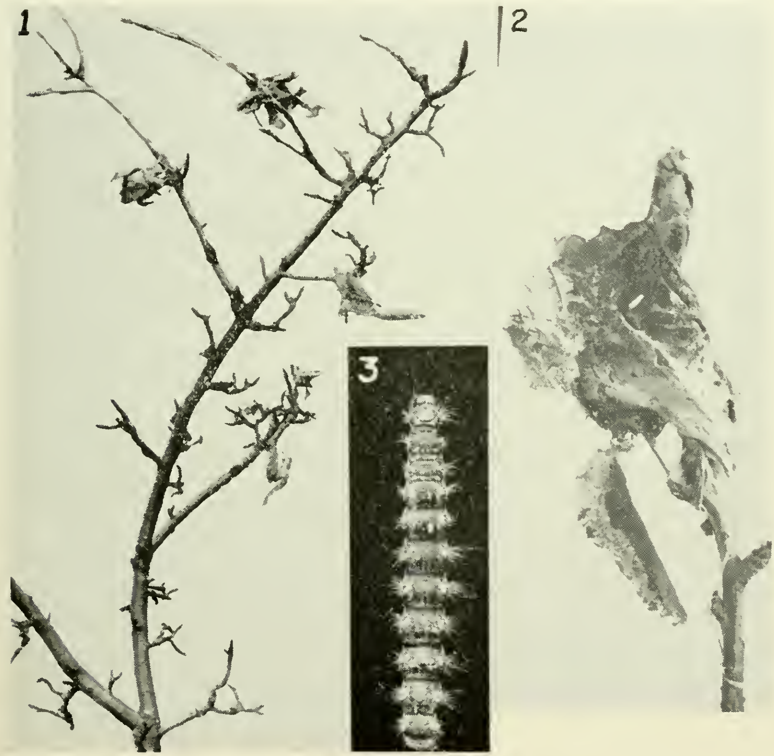
Brown-tail Moth

Nygmia phaeorrhoea Don.

The brown-tail moth was first reported in America at Somerville, Massachusetts, in 1897, probably having been introduced a few years earlier on nursery stock. For a number of years it spread throughout New England, doing considerable damage by defoliating deciduous hardwood trees. It has spread into New Brunswick and Nova Scotia, but in late years has caused much less injury. At the present time the limit of the quarantined area in eastern Massachusetts extends, roughly, diagonally across Worcester County from the northwest corner to the northeast corner of Connecticut.



Brown-Tail Moth

1. Winter nests on a pear tree. Much reduced.
2. Winter nest. Actual size.
3. Caterpillar. Slightly enlarged.

Figs. 1 and 2, Courtesy, Conn. Agr. Expt. Station.

It is reported that the caterpillars do not feed on coniferous evergreens but feed on numerous deciduous hardwoods, showing a preference for pear, apple, stone fruits, oak, willow, and rose. They will feed on elm and maple also but seldom injure hickory, ash, chestnut, or birch. Most of the injury to the trees is caused by the feeding of the older caterpillars in the spring. In severe infestations they may eat the leaves as fast as they are produced, completely stripping many trees. The young caterpillars which hatch in August and skeletonize the leaves do not harm the trees to any extent because the growing season is almost completed. The growth of the trees may sometimes be checked because of the webs formed on the terminal parts of the branches.

In addition to the injury done to foliage, the moths and caterpillars constitute a nuisance to man and animals. Their bodies bear barbed hairs which are hollow and contain a poison which affects the blood corpuscles. When these hairs come in contact with tender skin, they cause severe irritation which produces a rash and swelling. The hairs may be blown by the wind for a considerable distance and poison people by touching them directly or by getting into clothing hung out of doors. If any of the hairs are inhaled, serious internal irritation may ensue.

Description. The moths of both sexes are pure white except for the tip of the abdomen which is covered with brown hairs. The female is slightly larger than the male.

The eggs, which are laid in irregular masses on the under side of leaves, are covered with brown hairs from the body of the female. The masses vary in size and shape, being from ½ to ¾ inch long and about ¼ inch wide.

The full-grown caterpillars may attain a length of 1½ inches. They are brown with light brown hairs. Along each side there are white markings which from above give the appearance of a series of white dashes. On the top of both the ninth and tenth body segments there is a red tubercle.

The pupae are about ½ inch long and dark brown in color. They are in cocoons which are enclosed in a few leaves that have been webbed together.

Life History. In early July the female moths lay their eggs in brownish clusters on the under side of leaves. They are on the wing about two weeks. About mid-August the eggs begin to hatch and the young caterpillars feed in groups on the surface of the leaves, skeletonizing them. The larvae molt once or twice and then, about September, the caterpillars which hatched from the same egg cluster begin to draw together with silken threads several leaves near the tips of a branch and fasten them to the twigs. They pass the winter in these webs. In the spring, about the time the buds begin to develop, the caterpillars leave their winter webs and feed upon the bud scales and small leaflets. Only the larger leaf veins are left. Blossoms and the fruit of some trees may be eaten when the caterpillars are abundant. The larvae reach maturity about the middle of June. Each caterpillar then fastens together a few leaves with silken threads and spins a cocoon inside, pupating within it. Sometimes several cocoons are found together in the same bunch of leaves. Two to three weeks may be spent in this stage. The moths begin to emerge in early July and soon lay their eggs.

Control. The foliage may be sprayed with lead arsenate in August when the young caterpillars begin to feed on the leaves. This is the usual time to apply the spray because in the spring the older caterpillars often eat the leaves as fast as they appear so that not enough leaf surface is present to hold a poison spray. Not less than 3 pounds of lead arsenate to 100 gallons of water should be used. A sticker may be used on shade or ornamental trees but should not be applied to fruit trees, especially early fall varieties, because of the spray residue which would be left on the fruit.

In the winter the nests may be cut off and burned. This is a very effective and satisfactory method when it can be put into effect.

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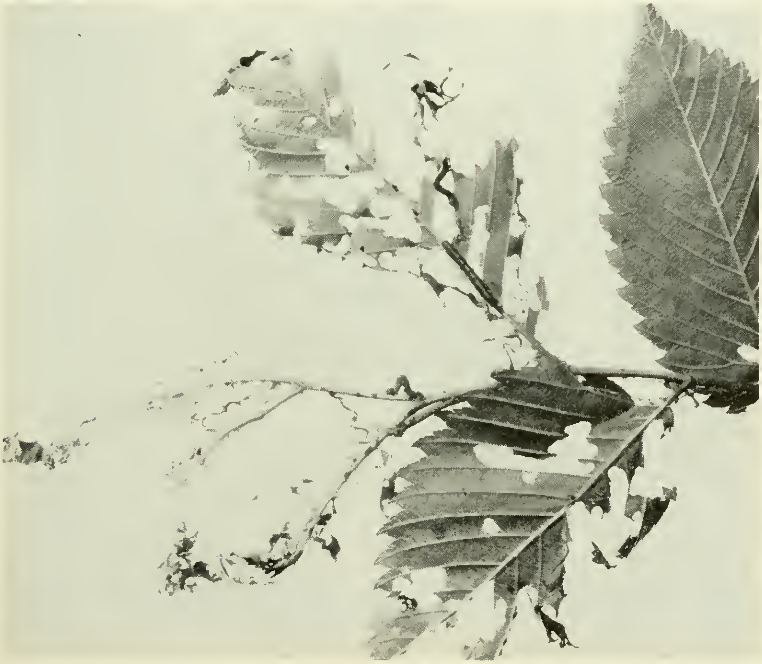
Fernald, C. H., and Kirkland, A. H. Hatch Exp. Sta., Mass. Agr. Col. Spec. Bul. 1897.

Cankerworms

The Fall Cankerworm, *Alsophila pometaria* Harr.
The Spring Cankerworm, *Paleacrita vernata* Peck.

The cankerworms, also known as measuring or inch worms, or sometimes as loopers, attack the leaves of numerous broad-leaved trees in the northeastern United States. They are known to be especially injurious to elms and apples. At various times, elms in different parts of Massachusetts have been severely defoliated by these insects. Both kinds of cankerworms may be found on the same trees. One lays its eggs very late in the fall and is, therefore, called the fall cankerworm; the other lays its eggs very early in the spring and is known as the spring cankerworm. Both hatch at about the same time in the spring, and the young caterpillars may be found feeding together soon after the leaves have appeared.



Elm Leaves Injured by Cankerworms.

Description. The two species may be told apart in their various stages by the following characteristics:

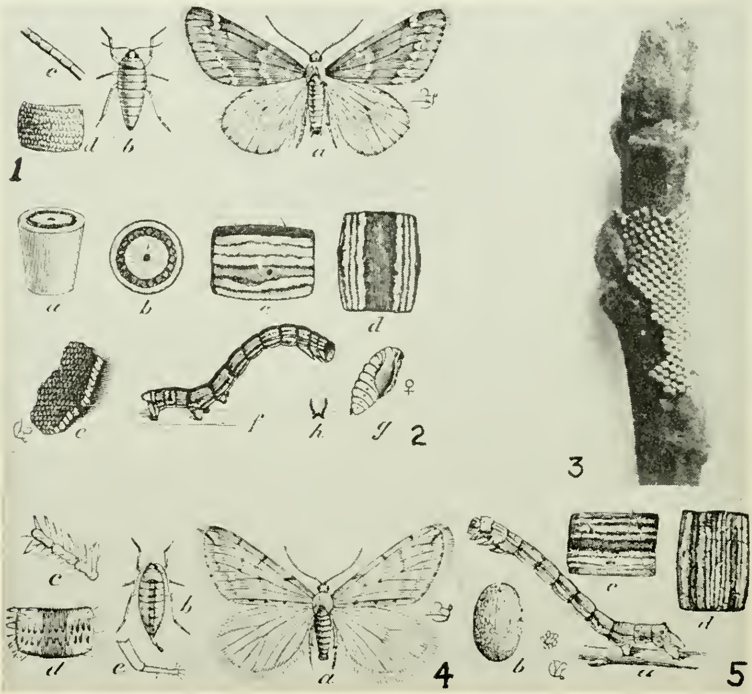
In both species the female moths are wingless. The female of the fall species is uniformly gray, while the spring species has a dark, longitudinal stripe on its back. In both species the male moths are winged and are a brownish gray, the fall species being darker. The adults of both sexes of the spring species have on the top of the first seven abdominal segments a transverse row of sharp reddish spines projecting toward the rear. In the fall species this is absent.

The individual eggs of the fall species are shaped like a flower pot, are flat on top, and fairly smooth on the side; whereas those of the spring species are oval in shape and ridged on the side.

The caterpillars vary in color and have several thin longitudinal stripes on their sides. The fall species can be distinguished from the spring species because it has three pairs of abdominal legs near the posterior end, whereas the spring species has only two.

The pupa of the fall species is dark brown in color. The apex is rather blunt, and the apical spine decurved and always forked. The spring species is more sharply pointed and the apical spine is usually simple. The pupal cells, or cocoons, of the fall species have more threads of silk than those of the spring species and are not so easily broken.

Life History. The moths of the fall cankerworm emerge from the ground on warm days in the late fall and early winter. The wingless females climb up trees and lay their eggs in regular clusters of about 100 on twigs and branches. The eggs hatch about the time the leaves begin to show and the young caterpillars begin to eat holes in the young leaves, soon devouring everything but the larger veins. When disturbed they drop on silken threads and may then be



Cankerworms

1. Fall cankerworm. a. Male moth 1×. b. Female moth 1×. c. Joints of female antenna. Enlarged. d. Joints of female abdomen. Enlarged.
2. Fall cankerworm. a, b. Egg, side and top views. Enlarged. c, d. Body joints of caterpillar, side and top views. Enlarged. e. Egg mass 1×. f. Mature caterpillar 1×. g. Female pupa 1×. h. Anal tubercle of pupa, top view. Enlarged.
3. Fall cankerworm egg mass on twig. Enlarged. Courtesy, Mich. Agr. Expt. Station.
4. Spring cankerworm. a. Male moth 1×. b. Female moth 1×. c. Joints of female moth's antenna. Enlarged. d. Joint of female moth's abdomen showing spines. Enlarged. e. Female moth's ovipositor. Enlarged.
5. Spring cankerworm. a. Mature larva 1×. b. Egg. Enlarged. c, d. Joint of caterpillar's body, side view and top view. Enlarged.

Figs. 1, 2, 4, and 5, by C. V. Riley. Courtesy, Missouri Dept. Agr.

blown to other trees by the wind. In early June the caterpillars drop or crawl to the ground, spin cocoons just below the surface of the earth, and there pupate, the adult moths appearing in late fall to lay their eggs. There is only one generation a year.

The moths of the spring cankerworm emerge from cocoons in the ground late in the winter or very early in the spring. The wingless females climb the trees and lay their eggs in loose irregular clusters in crevices on the bark. These eggs hatch about the same time as those of the fall cankerworm and the caterpillars feed on the leaves, causing the same type of injury. They mature in early June and then go to the ground to pupate in cocoons. There is one generation a year.

Control.

1. Sprays. Adequate control can generally be obtained by spraying with lead arsenate in the spring as soon as the leaves are large enough to hold a poison spray. Powdered lead arsenate may be used at the rate of 4 or 5 pounds to 100 gallons of water with 2 pounds of flour or 1 pound of calcium caseinate added as a sticker. If only one application is to be made, it should not be applied too early, because the leaves which develop later will not be poisoned and so may be eaten. However, in severe infestations the caterpillars may eat the leaves as fast as they appear, at no time leaving enough leaf surface to poison. In this event, before much damage occurs, it may be advisable to spray with or add to the lead arsenate, a contact insecticide such as 40 percent nicotine sulfate. This may be added to the lead arsenate in the proportion of 1 pint to 100 gallons of the lead arsenate spray. Rotenone, derris, or pyrethrum may be substituted for the nicotine sulfate and should be mixed according to the directions of the manufacturer. All these contact sprays kill by touching the insect, so care should be taken to hit the insects directly. Because the young opening leaves are more susceptible to spray burning than older ones, it would be safer to apply not more than 3 pounds of lead arsenate in 100 gallons of water to foliage sprayed at that time. If a later application is necessary, 4 or 5 pounds of the powder may be used.

Spraying with lime-sulfur or nicotine sulfate in the spring before the buds begin to swell, has also been advised, to kill the eggs in localities known to be heavily infested. The lime-sulfur spray may be mixed in the proportion of 1 part of liquid lime-sulfur (33° Baume) to 9 parts of water. The nicotine sulfate spray may be mixed in the proportion of 1 pint of 40 percent nicotine sulfate to 100 gallons of water.

2. Sticky Bands. Because of the wind drift of the insects, banding is not advised where the trees to be protected are close together. However, banding should prevent severe injury to trees not yet infested which stand off by themselves. Sticky bands can be placed around the trunks of isolated trees in late October to prevent the wingless moths from climbing to lay eggs. These bands should be kept sticky during November and December for the fall cankerworm moths. They should be renewed in the early spring just before the frost leaves the ground and kept sticky until the end of May to prevent the wingless moths of the spring cankerworm from ascending to lay their eggs in the early spring, and to prevent the caterpillars from crawling up to feed when the leaves appear.

It is best to place the sticky bands on strips of cheap cotton batting, which should securely fill up all bark crevices to prevent insects from crawling through underneath. Regular banding strips are for sale on the market.

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Fernald, C. H. Hatch Exp. Sta. Mass. Agr. Col. Bul. 20:4-6. 1893.
Hartzell, A., and Youden, W. J. Contrib. Boyce Thompson Institute 7(3): 365-377. 1935.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:30-33. 1933.

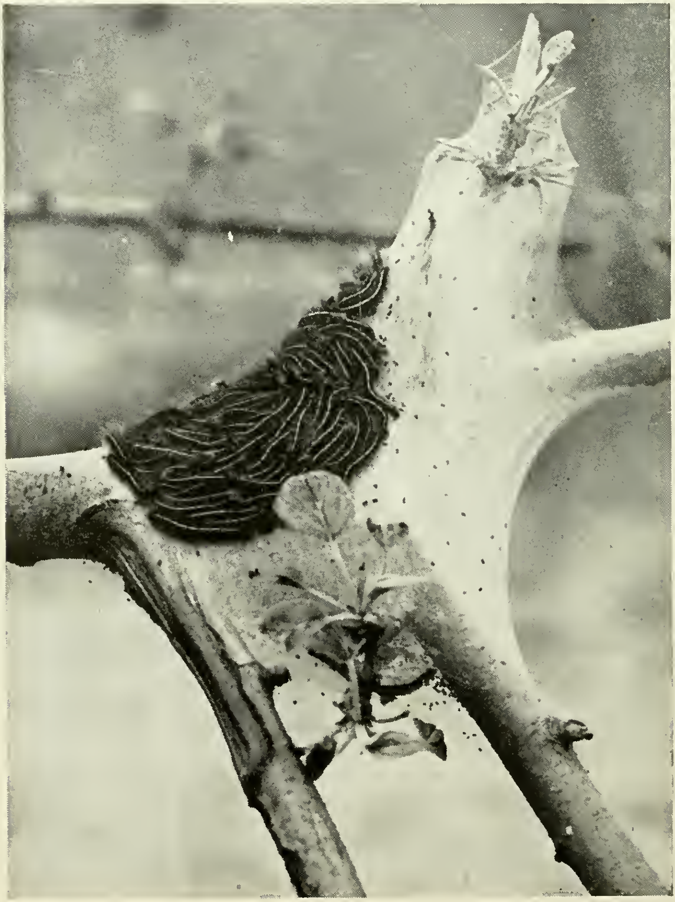
Eastern Tent Caterpillar

Malacosoma americana F.

This insect is a native of North America where it is known to have been a pest since 1646. It feeds upon the foliage of several trees and shrubs and, when abundant, may cause complete defoliation. Except in severe cases, however, caterpillars themselves and their unsightly gray nests are even more annoying than the actual damage done. The favorite hosts are black cherry, fire cherry, and chokecherry. Next to these, apple is undoubtedly most preferred.

Description. The adult female measures about 1½ inches across the expanded wings; the male about 1 1/8 inches. Both are reddish-brown with two oblique whitish stripes on each front wing.

The eggs are grayish in color, about 1/8 inch long, and laid on end in clusters of about 350. The cluster, which commonly encircles a small twig but sometimes only partly surrounds it, is covered with a protective coating, brown to black in color, which when newly deposited gives the cluster a varnished appearance.



Eastern Tent Caterpillars on Their Characteristic Tent.
Photo by Robert L. Coffin.

In many cases this protective covering is removed by weather conditions during the fall and winter.

The young caterpillars are almost black. The full-grown caterpillars are about 2 to 2½ inches in length. The ground color is black with a white stripe along the back and irregular brownish or yellowish markings on each body segment. The sides are bluish with an oval blue spot nearly surrounded by black on each segment.

The pupae are slightly less than 1 inch long and are dark brown. They are enclosed in white, oval cocoons which are a little over 1 inch long and about ½ inch thick. These cocoons are made of loosely woven silken threads, and are usually attached by one side to some object in a more or less protected place.

Life History. The insect passes the winter as a larva, or caterpillar, in the egg. The eggs hatch in April and the young caterpillars feed at first on the protective covering of the egg cluster but soon attack the new leaves. Within a few days the larvae begin to spin a nest, usually in a fork of a branch. They leave the nest to feed, and as they crawl to the leaves they spin a silken thread. When the insects are very abundant the branches of a tree may become whitened by these threads. In from 4 to 6 weeks the caterpillars become full grown. They then leave the trees and crawl to some sheltered place where they spin yellowish-white cocoons in which they transform to pupae. These cocoons may be found in grass, under rubbish, in crevices in bark, or on buildings. The pupal stage requires about 3 weeks for its completion. Soon after the adults emerge, mating takes place and the eggs for the next season's brood are deposited.

Control. During many seasons this pest is satisfactorily controlled by its natural enemies. Every 10 to 12 years, however, the caterpillars reach epidemic proportions and may remain at this peak for 2 or 3 years. Such periods may not occur at the same time throughout the State. As a result the insect may be abundant in one section of the State and comparatively scarce in another.

Artificial measures of control during periods of abundance consist of the following:

1. Destruction of egg masses. This is an effective method. In the winter these egg masses are conspicuous on the small twigs. They should be pruned off and *destroyed* because if they drop to the ground and are allowed to remain there, practically a normal hatch may result. To be effective, this should be done before the larvae emerge; in other words, before April.

2. Destruction of the tents containing the caterpillars. This may be a very valuable aid in the control of the pest provided it is done while the tents are still small and can be easily removed. At that time the caterpillars would not have done any extensive feeding. If removal of the nests is delayed until they have become large, much of the damage will have been done.

To remove the nests a stiff brush mounted on a pole, or a pole with several nails driven in one end, can be employed. This instrument is inserted into the nest and twisted so that the web is wrapped around it. Then the pole is removed and the caterpillars crushed. This should be done on cold, cloudy days when practically all the caterpillars are within the nests.

The practice of attempting to burn the tents should be discouraged. It is comparatively ineffective because many of the larvae drop to the ground, crawl away, and may eventually reassemble, causing further damage. Moreover, the burning is apt to cause serious injury to the bark, which may be more disfiguring than the work of the caterpillars.

3. Spraying. Lead arsenate, 3 pounds of the powder to 100 gallons of water, is effective and should be applied as soon as sufficient leaf surface is present to

retain the spray. The value of this method is demonstrated annually in commercial apple orchards where the pest is so well controlled by the pre-blossom sprays that growers feel little or no concern about this species in their orchards.

Bourne, A. I., and Shaw, F. R. Mass. Ext. Leaflet 167. 1937.
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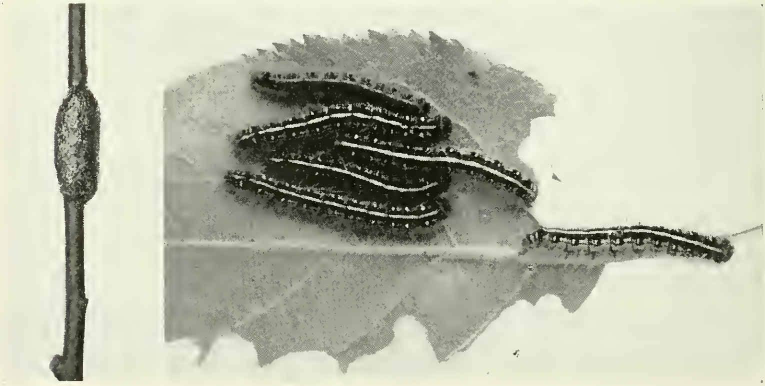
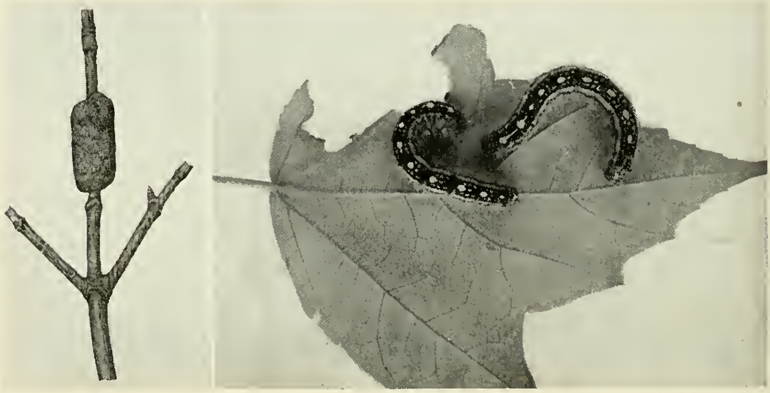


Eastern Tent Caterpillar.
Left, egg mass; right, mature caterpillars. Courtesy, Conn. Agr. Expt. Station.

Forest Tent Caterpillar

Malacosoma disstria Hbn.

The forest tent caterpillar is closely related to the eastern tent caterpillar and is often mistaken for it. Unlike the latter species, however, this insect makes no nest and the caterpillars feed independently most of their lives. When nearly mature they congregate on the trunks of trees in somewhat the same way that the eastern tent caterpillars cluster on the outside of their nest. The forest tent caterpillar is blue in appearance with a row of keyhole-shaped white spots on its back instead of a white stripe. The moth is slightly paler and has dark instead of white oblique stripes on its front wings. The ends of its egg clusters are squared



Forest Tent Caterpillar.
Left, egg mass; right, mature caterpillars. Courtesy, Conn. Agr. Expt. Station.

off and less pointed than those of the eastern tent caterpillars. Although in this vicinity the species is quite common on sugar maple, oak, birch, and poplar, several other broad-leaved fruit, forest, and shade trees are attacked. Occasionally large areas of woodland may be defoliated.

Control. Lead arsenate as recommended for the eastern tent caterpillar is the most effective method of control for this species.

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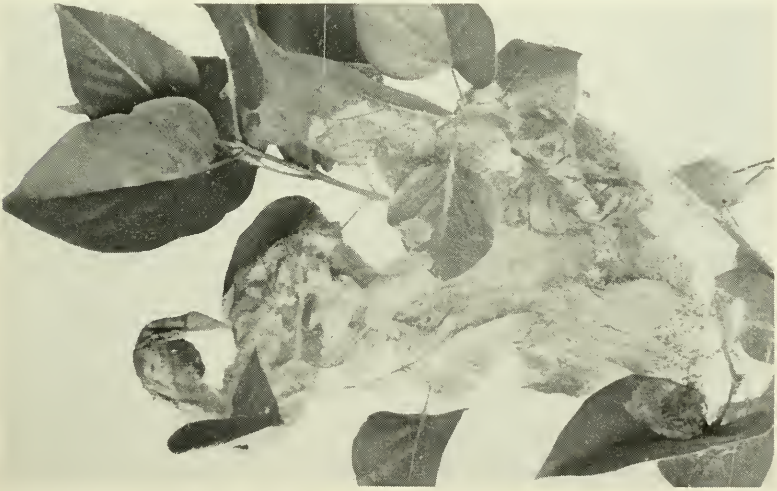
Fall Webworm

Hyphantria cunea Drury

This is a native insect which is distributed throughout the United States and parts of Canada. There are two forms which are considered by some writers to be two distinct species; while others hold that the two are identical or that one is a variety of the other. The northern form is often designated as *H. textor.*

The caterpillars make conspicuous silken webs around the foliage at the ends of the branches in late summer. They feed in colonies on the leaves enclosed in their webs, and as more food is needed, they enclose more leaves. They are often mistaken for eastern tent caterpillars. The tent caterpillars, however, make their webs at the crotches of limbs and branches in the spring, and only return to their webs or tents when not feeding, usually at night and on cool, dark days.



Nest of Fall Webworm on Lilac.

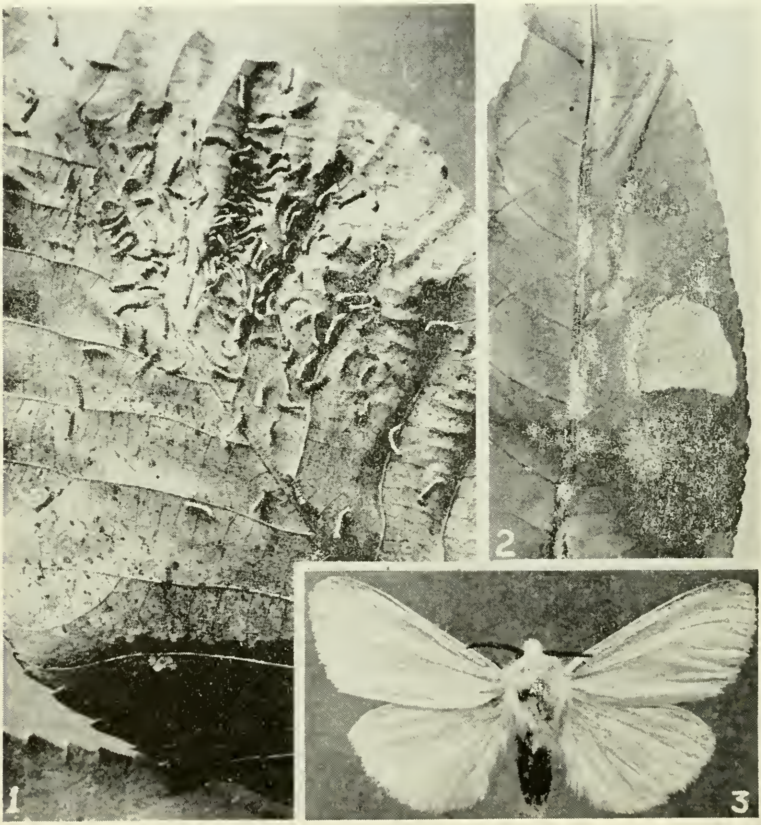
The fall webworm caterpillars usually attack only an occasional limb so that the injury is not serious, but the mass of webbed leaves gives a very unsightly appearance to the tree. Entire trees, however, have been known to be defoliated and in such cases damage is serious. The insect is reported to attack 120 kinds of plants, including many broad-leaved deciduous fruit, forest, shade, and ornamental trees and shrubs as well as some flower and vegetable garden plants.

Description. The moths have a wingspread of about 1½ inches. The wings vary from pure white to white with black spots, which differ in number in different individuals.

The eggs are laid in clusters on the under side of the leaf. Several hundred have been found in a single cluster. The eggs are round, about 1/50 inch in diameter, and the surface is finely pitted or sculptured. They are yellowish when first laid, but turn to a dull lead color just before hatching.

The newly hatched caterpillar is pale yellow, sparsely haired, and has a black head and two rows of black markings along the body. The mature caterpillar is about 1¼ to 1½ inches long and has an abundance of long hairs which arise in tufts from tubercles along its body. It is yellowish in color, with black and brown markings which vary considerably in appearance.

The oval cocoon is thin and mixed with hairs from the body of the caterpillar. When it is spun at or just below the surface of the ground, particles of soil may be entangled in its meshes. The pupa is brown and swollen at the middle, and some of the segments are divided by deep sutures. It is about ½ inch long.



Fall Webworm

1. Young caterpillars feeding on hickory leaf. Actual size.
2. Egg cluster on peach leaf. Actual size.
3. Adult female moth. 2×.

Courtesy, Conn. Agr. Expt. Station.

Life History. Farther south the fall webworm may have two generations; in northern Connecticut, Massachusetts, and northward, however, it is reported to have only one.

The adult moths are abroad in June and July and lay their eggs in clusters on the under side of a leaf. The eggs soon hatch and the tiny young caterpillars working gregariously begin at once to enclose in a silken web the leaves on which they feed. As more food is needed, the web is extended to include more leaves until finally the webs may be of considerable size and include whole branches. These webs usually become noticeable during August and September. The young caterpillars feed mostly on the upper surface of the leaves, skeletonizing them, but the older larvae eat the entire leaf leaving only the midrib and larger veins. After feeding for about a month the caterpillars become mature, leave the nest, wander off individually, and soon select a protected place in which to pupate — under loose bark or in a crevice of a tree, on a fence, or under rubbish, leaves or stones on the ground. Some may even burrow below the surface. The larva spins a loose cocoon in which long hairs from its body are enmeshed. It then pupates and passes the winter in that condition. The adult moths appear the following June.

Control. Spraying the trees with lead arsenate at the rate of 3 to 4 pounds of the powder to 100 gallons of water with 2 pounds of flour or 1 pound of calcium caseinate added should protect the foliage from injury if done when the caterpillars first appear. It is difficult to kill with this spray caterpillars that are more than half grown.

When the webs are within reach of pruning tools they may be removed and burned, provided they have not become so large that removing the infested parts disfigures the tree. When the webs can be reached by hand and are still small, they may be removed and the caterpillars crushed or dropped into a can of kerosene and water.

Burning the webs on the tree by means of an ignited kerosene-soaked rag on a pole is not advised because the branches may be scorched in the process.

Parasites, predators, and diseases do much to hold this insect in check.

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White-Marked Tussock Moth

Hemerocampa leucostigma S. & A.

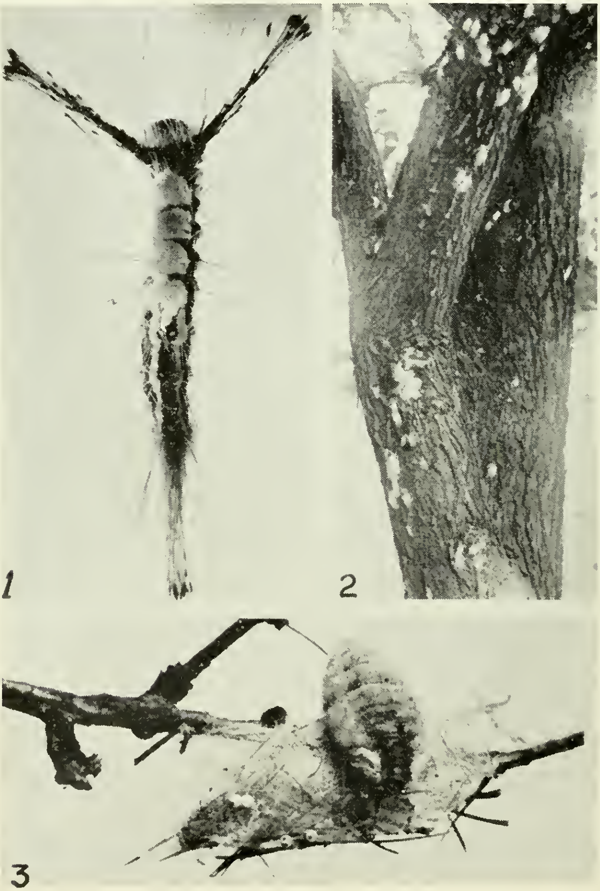
This native insect is generally distributed from Nova Scotia to Florida and west to Nebraska but has been most troublesome in southern New England and the Middle Atlantic States. It is more of a pest in cities and towns than in rural sections, and prefers the foliage of broad-leaved trees such as poplar, elm, linden, soft maple, and horsechestnut, but feeds on many others, including coniferous trees such as spruce, fir, larch, and cypress.

The young caterpillars feed at first on the lower leaf surface but later devour all the tissue, leaving only the midrib. The caterpillars have been reported to girdle the twigs of elm by eating the bark around the twig near the beginning of the season's growth. The affected tips soon die, break off, and fall to the ground. The fruit of orchard trees is occasionally attacked.

Severe local defoliations by this insect sometimes occur at irregular intervals, following which there are periods of practically no damage due chiefly to the activity of the predators and parasites of the insect. Insectivorous birds and bacterial diseases also take their toll.

Description. The female moth is light gray in color, wingless except for small rudimentary stubs, and has simple, threadlike antennae. The male moth is grayish-brown, has normal wings with a spread of about 1¼ inches, and has large, feathery antennae.

The individual eggs are almost round, about 1/25 inch in diameter, and white or yellowish in color with a light brown spot surrounded by a ring of the same color. They are laid in masses of 100 to 700 on the empty cocoons of the female and covered with a white frothy material which soon hardens and becomes brittle, thus forming an effective protection.



White-Marked Tussock Moth.

1. Caterpillar. (Note two pencils of hair forward and one at rear.) Slightly enlarged. Courtesy, N. H. Agr. Expt. Station.
2. Cocoons on branch of a tree.
3. Wingless adult laying eggs on cocoon. Slightly enlarged.

Figs. 2 and 3, Courtesy Mich. Agr. Expt. Station.

The mature caterpillar is about 1½ inches long with four dense, white, brushlike tufts of hair on its back. Behind these are two shiny red wartlike growths. The head is brilliant coral red. There are two long pencils of black hair, about ½ inch long, which extend forward, arising just back of the head, one on each side. A single pencil of hair extends backward from the rear of the body. A broad black band extends almost the entire length of the back and is bordered by a yellow band on each side. The yellow bands are bordered with dark gray. Through the spiracles along the side there extends a thin black stripe. On the sides of the body are clusters of white bristles, with a brilliant black bristle occasionally intermingled.

When ready to pupate, the mature caterpillar spins a thin cocoon into which are woven the long hairs from its body. Sometimes the cocoons occur in great masses. Inside the cocoon the caterpillar transforms to a yellowish-white pupa which is more or less shaded with dark brown or black. The male cocoons average about 9/16 inch in length; the female, about 11/16 inch.

Life History. The insect passes the winter in the egg stage. The eggs hatch in early May and the tiny caterpillars feed on the green tissues of the lower leaf surface, skeletonizing the leaves. When disturbed the caterpillars drop, suspending themselves on silken threads, and may then be blown by the wind sometimes for a considerable distance. When nearly full grown, the caterpillars crawl about, often migrating to other trees. In about 5 weeks they mature and spin their cocoons on the bark of the trunks, branches, and even twigs, among leaves, or sometimes in protected places on near-by buildings and fences. The moths emerge in about 2 weeks. After mating, the females deposit their eggs for the next generation. In the vicinity of Albany there is normally one generation annually; in the vicinity of Boston and New York City and in Connecticut there are two generations a year.

Control. Spraying the foliage thoroughly, especially the under side of the leaves, when the caterpillars of the first generation are still very small in the spring, is the preferred method of control. About 4 pounds of lead arsenate to 100 gallons of water should be used, with 2 pounds of flour or 1 pound of calcium caseinate added as a sticker.

Egg masses may be collected and burned or they may be painted with creosote as are those of the gypsy moth. Many of the egg masses of this insect, however, are laid near the tops of the trees and in other inaccessible places. If the infested trees are small and other conditions are such that most of the egg masses can be reached and destroyed, this method gives good protection. The degree of infestation should also be considered. Hand-picking operations are too expensive for use in severe outbreaks.

Isolated trees which are free from attack may have the trunks banded with tanglefoot or other sticky substance to prevent mature, migrating caterpillars and wingless female moths from climbing up into them.

The parasitic insects, diseases, and insectivorous birds which prey upon this insect are instrumental in holding it in check except for occasional outbreaks.

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Lintner, J. A. N. Y. State Mus. Rpt. 49:124-126. 1896.
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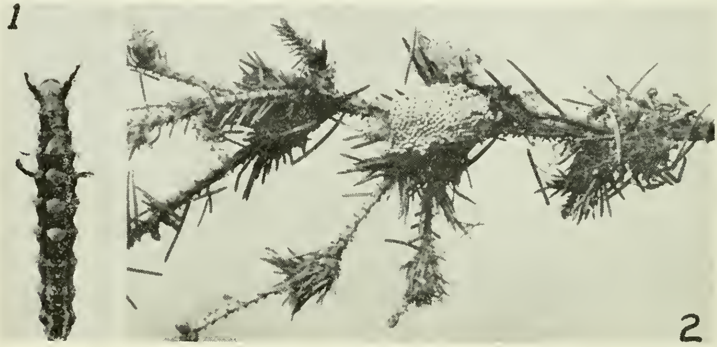
Rusty Tussock Moth

Notolophus antiqua L.

This insect, sometimes called the antique moth, is a European pest now known to be present in northeastern United States and southeastern Canada and also on the Pacific Coast. It attacks the foliage of several deciduous orchard and shade trees and is reported to feed on some coniferous evergreens, but usually is not abundant enough to cause serious injury.

Its life history is similar to that of the white-marked tussock moth except that the eggs laid on the cocoons are not covered with frothy material.



Rusty Tussock Moth

1. Caterpillar. (Note two pencils of hair forward and two at side.) Actual size.
2. Egg mass on spruce twig. Courtesy, Mich. Agr. Expt. Station.

The full-grown caterpillars may be distinguished from those of the white-marked and other tussock moths by their black head, darker body, and the presence of two additional pencils of long black hairs, one on each side, about midway of the body.

The female moth is gray and wingless. The male is rust-brown and has wings, the front pair being crossed by two darker bands and bearing a conspicuous white spot near the rear border.

Control measures are the same as those recommended for the white-marked tussock moth.

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Fernald, C. H. Hatch Exp. Sta. Mass. Agr. Col. Bul. 20:15-16. 1893.
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Satin Moth

Stilpnotia salicis Linn.

The satin moth, which is a native of Europe, was first found in the United States near Boston in 1920. Since then it has spread throughout Massachusetts, Rhode Island, most of Connecticut, southeastern New Hampshire, and southwestern Maine. Localized infestations have been reported in eastern Canada and there is also a large infestation on the West Coast in British Columbia and the State of Washington.

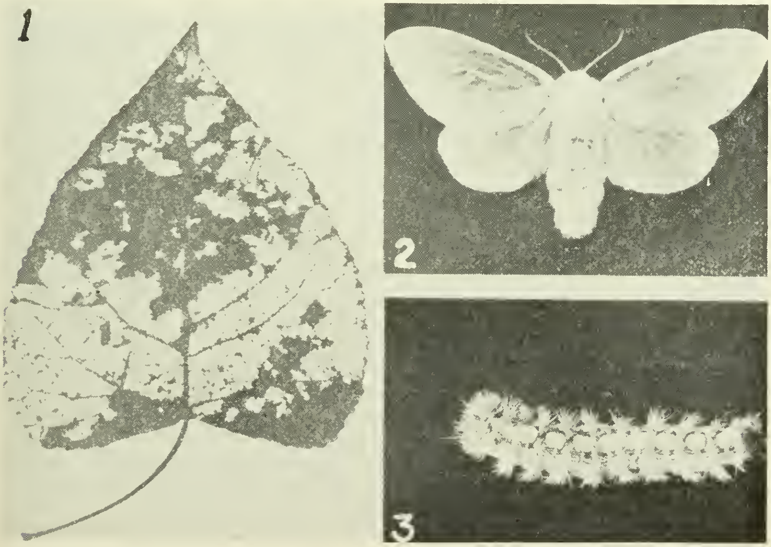
The caterpillars prefer the foliage of poplar, aspen, and willow, and most of the injury is confined to these hosts, entire trees and groups of trees having been defoliated.

Description. The moths of both sexes are entirely white with a satiny luster. The female has a wingspread of about 2 inches. The male is slightly smaller.

The individual eggs are minute, round, and slightly flattened. They are pale green when first laid but gradually turn brown. They are laid in one or two layers in flat, oval masses about ½ inch wide and 3/5 inch long, and are covered with a white secretion that glistens in the sun. A single mass may contain 100 to 300 or more eggs.

The full-grown caterpillars are about 1½ to 2 inches long. The head is black. The body is black with fine white markings. Along the back is a series of large whitish blotches varying from almost square to dumbbell shape. Along each side are two thin, broken, whitish lines. On each body segment there is a transverse row of brown tubercles each bearing a tuft of long hairs.

The pupa is almost 1 inch long. It is shining black and covered with tufts of long whitish to golden hairs on all but the ventral surface. The cocoon is loosely made of silken threads and attaches the pupa, which is easily seen through the cocoon, to a leaf, twig or other object.



Satin Moth

1. Injured poplar leaf.
2. Adult female moth. Actual size.
3. Caterpillar. Actual size.

Figs. 1 and 2, Courtesy, Bur. Ent. and Plant Quarantine, U. S. Dept Agr.

Life History. Partially grown caterpillars (third stage) pass the winter under a small, firm web which is usually constructed in crevices of the bark or in other protected places. From late April through May they emerge from hibernation and feed on the foliage. They molt seven times as they mature and finally become full grown the latter part of June. They then pupate in loosely made cocoons which are usually spun in folded leaves but sometimes in crevices of the bark, on buildings, on fences, in rubbish, and in other places near their host plants. About 10 days later the white, satiny moths begin emerging. In late June and during July the moths are on the wing. They soon mate and the females lay their eggs in small masses on the bark, leaves, or adjacent fences or buildings. The eggs hatch in about 2 weeks. The tiny caterpillars of the first two stages feed on either surface of the leaves, usually the lower, skeletonizing them. After feeding for several days the first stage caterpillars spin a thin, small web in a bark crevice or on the back of a leaf and change to the second stage. They feed for about the same length of time and then spin a small, firm web or winter case in which they change to the third stage, in which they hibernate. Usually there is only one caterpillar to a web but in severe infestations two or more may occur. There is one generation a year.

Control. The best control is obtained by spraying the foliage with lead arsenate in the spring to kill the caterpillars when they begin to feed. To 5 pounds of lead arsenate and 100 gallons of water add 1¼ pints of light pressed menhaden fish oil or raw linseed oil to make the spray adhere to the waxy foliage of the host plants. The lead arsenate should be mixed with a small amount of water and stirred to form a thin paste. The oil should then be added, stirred until evenly distributed, and then poured into the tank just before spraying is started.

The egg masses may be killed with an application of creosote in July soon after the eggs are laid, but inasmuch as many egg masses are deposited on leaves and small twigs this method of control is not so efficient as spraying.

Birds and parasitic insects attack the satin moth and do much to hold it in check.

Britton, W. E. Conn. State Ent. Rpt. 32:415-416. 1933.
Britton, W. E. Conn. State Ent. Rpt. 36: 361-364. 1937.
Burgess, A. F. U. S. Dept. Agr. Dept. Circ. 167. 1921.
Burgess, A. F., and Crossman, S. S. U. S. Dept. Agr. Bul. 1469. 1927.
Collins, C. W., and Hood, C. E. U. S. Dept. Agr. Circ. 189. 1931.
Glendenning, R. Can. Dept. Agr. Pamphlet 50, N. S., 1932.

Saddled Prominent

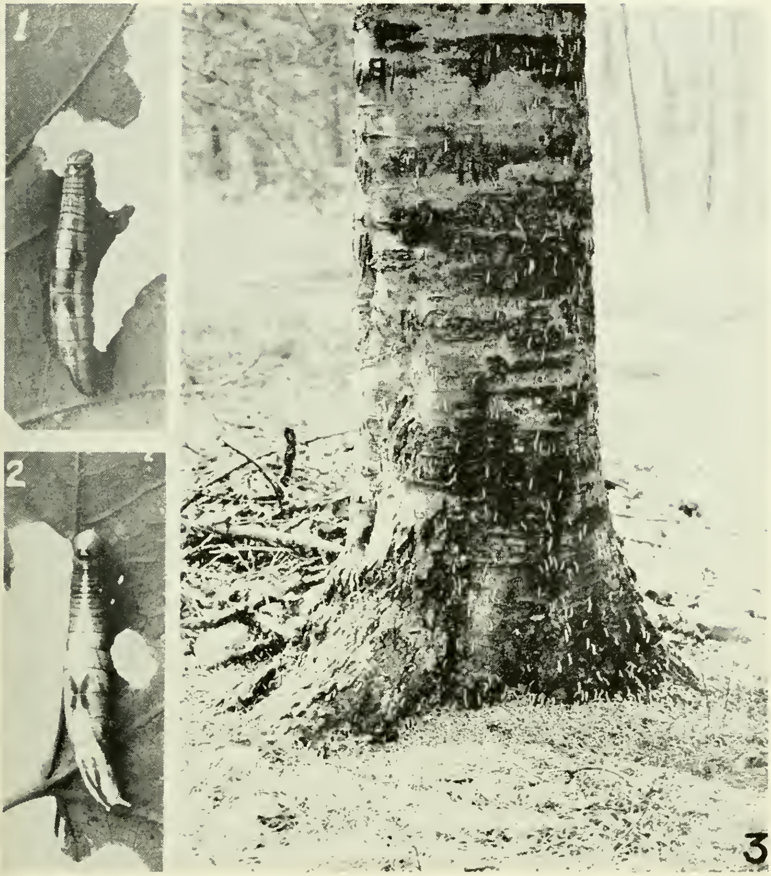
Heterocampa guttivitta Walk.

This insect, sometimes called the antlered maple worm because of the antlerlike horns on the young caterpillars, is a native species generally distributed throughout the northeastern United States and eastern Canada. The natural enemies of this insect keep it under control for the most part, but occasionally it becomes very abundant and may defoliate considerable areas of hardwoods. The foliage of beech and sugar maple is preferred, but oak, birch, apple, and other deciduous hardwoods are also attacked. The insect is an enemy of woodland trees rather than of isolated shade trees in cities or parks, and generally stands of trees on hillsides are more severely attacked than those in the lowlands.

Description. The female moths have a wingspread of about 2 inches. They are olive-green or greenish-brown flecked with splotches of creamy-white and black. The males are slightly smaller than the females and generally darker in color.

The tiny eggs are circular, pale green in color, and laid separately on the leaves.

The newly hatched caterpillars have antlerlike horns on the top of the first body segment just behind the head. Other horns, less prominent, are also found along the body. The horns disappear after the caterpillar molts the first time.



Saddled Prominent

1 and 2. Caterpillars on leaf. Actual size.
Courtesy, Conn. Agr. Expt. Station.
3. A cluster of hungry caterpillars at the base of a tree.
Courtesy, Mich. Agr. Expt. Station.

The mature caterpillars are about 1½ inches long, are thickest about midway and taper toward the front and rear. They vary considerably in color and markings. Some are light yellowish-green, others nearly purple with intermediate variations. Many have, on the back, a light bluish-green area that is pointed toward the head, with a darker lavender or purple mark resembling a saddle just behind it about midway the length of the body. This saddle, however, varies in shape and size among individual caterpillars and may be lacking in some specimens.

The pupa is about ¾ inch long, naked, and formed in a cell near the surface of the ground near the base of the host tree.

Life History. The moths begin to appear in late May or early June. Soon after emerging they mate and begin to lay eggs singly on the leaves. The eggs hatch in about 9 days. Apparently most of the eggs are laid in the upper parts of the trees since the caterpillars strip the tops of the trees first. The larvae molt four times and become full grown in about 5 weeks, depending on weather conditions and food supply. They may migrate from one tree to another and when abundant may collect in large numbers around the bases of defoliated trees. From about mid-July to late August the caterpillars go to the ground where they transform to pupae in the leaf mold or the soil beneath. They pass the winter there in the pupal stage and the moths emerge the following spring. There is one generation a year in New England although two generations have been reported occasionally.

Control. For the most part natural enemies keep this insect in check. When it is necessary to protect valuable stands of trees, however, a spray of 4 pounds of lead arsenate to 100 gallons of water, with 2 pounds of flour or 1 pound of calcium caseinate added to make the spray stick to the foliage better, will give satisfactory control if applied when the caterpillars first begin to feed. When only a few trees are attacked, the caterpillars may be jarred from the trees in the morning when it is cool and the insects are inactive. Encircling the tree with a sticky band, as recommended for the gypsy moth, will prevent their climbing back again.

Under some conditions, after caterpillars are jarred from the trees or when they are gathered in large numbers around the bases of the trees, it may be possible to kill them on the ground by mechanical means or a safe contact insecticide.

Britton, W. E. Conn. State Ent. Rpt. 30:468, 529-532. 1931.
Collins, C. W. Jour. Agr. Res. 32(7):689-699. 1926.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:20-22. 1933.
Patch, E. M., and Johannsen, O. A. Maine Agr. Exp. Sta. (383-6-10):25-27. No date.

Green-Striped Maple Worm

Anisota rubicunda F.

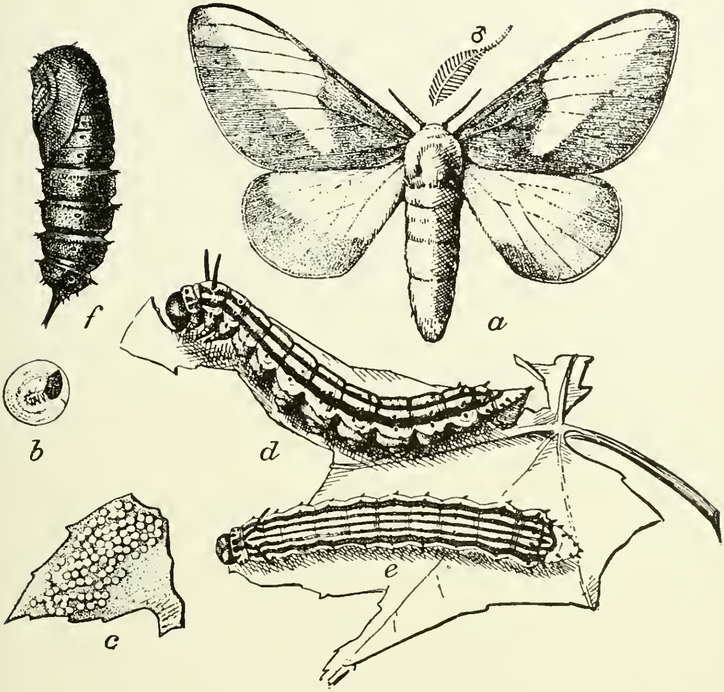
This native insect is widely distributed in the United States but appears to be more abundant in the West in Kansas and Missouri although serious outbreaks do occasionally occur in the East. The caterpillars evidently prefer the foliage of maples, especially silver and red maple, but occasionally attack box elder and oak.

Description. The moth has a wingspread of about 1½ to 2 inches. The forewings are rose-red crossed by a broad, pale yellow band. The body is yellow with the under side and legs rose-red. Eastern specimens appear to have the rose tints more intense, whereas in the western forms the yellow predominates. The male is slightly smaller than the female.

The eggs are about 1/25 inch in diameter, slightly flattened, and pale green in color which becomes yellowish before the larva emerges.

The newly hatched caterpillar is yellow with a large black head. Numerous short spines on the body form black tubercles of almost uniform size. The full-grown caterpillar is about 1½ inches long, pale yellowish-green in color and striped longitudinally above with alternate pale yellowish-green and darker green lines. The head is cherry red in color. Just behind it on the second body segment are two long, slender, slightly curved black spines. There are also shorter black spines along the body. At the side of the body toward the rear (the tenth and eleventh body segments) there is a slightly dilated rose-colored area.

The pupa is dark brown, hard-shelled, and slightly less than 1 inch long. The margins of the abdominal segments are armed with little spines. At the rear is a spinelike projection which is slightly forked at the tip.



Green-Striped Maple Worm

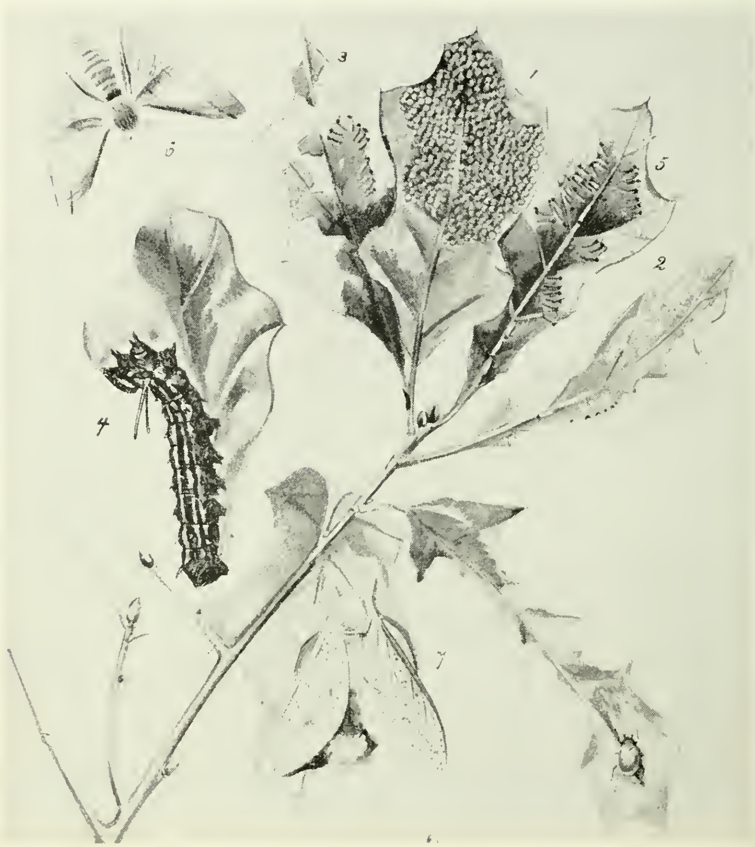
- a. Female moth and antenna of male moth.
- b. Egg showing embryo within.
- c. Portion of egg mass.
- d. Mature caterpillar, side view.
- e. Mature caterpillar, top view.
- f. Pupa.

All enlarged. Courtesy, Bur. Ent. and Plant Quarantine, U. S. Dept. Agr.

Life History. About May or June, depending on the locality, the moths begin to emerge from the overwintering cocoons. The eggs are deposited on the under side of the leaves, one female being capable of laying as many as 150 eggs. The eggs hatch in about 8 or 10 days, and the young caterpillars begin to feed on the leaves. In about a month, after molting four times, they become full grown, go to the ground, and work their way into the leaf mold where they transform to pupae. In northern New England it is likely that only one generation occurs, whereas farther south there may possibly be two.

Control. The most effective means of control is spraying the foliage thoroughly with lead arsenate, using 4 pounds of the powder to 100 gallons of water, with 2 pounds of flour or 1 pound of calcium caseinate added to increase the adhesiveness of the spray. This should be applied in May or June when the caterpillars of the first generation are young and easily killed.

Bailey, H. L. Vt. Dept. Agr. Bul. 35:26-27. No date.
Felt, E. P. N. Y. State Mus. Mem. 8(2):537-538. 1906.
Houser, J. S. Ohio Agr. Exp. Sta. Bul. 332:252. 1918.
Howard, L. O., and Chittenden, F. H. U. S. Dept. Agr. Bur. Ent. Circ. 110. 1909.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:56. 1933.



Orange-Striped Oak Worm

1. Egg mass on under side of oak leaf.
2. Egg shells on partly eaten leaf.
3. Part of leaf skeletonized by young caterpillars.
4. Side view of nearly full-grown caterpillar.
5. Recently hatched caterpillars feeding side by side.
6. Male moth.
7. Female moth depositing eggs.

All about actual size. Courtesy, N. Y. State Museum, Albany, N. Y.

Orange-Striped Oak Worm

Anisota senatoria S. & A.

This native insect has a wide distribution in this country. In the East it is generally distributed from Canada to Georgia, it occurs in most of the North Central States, and has been reported from California. It is said to be more abundant in the northern part of the United States than in the southern. The caterpillars prefer the foliage of oak but also attack maple, hickory, hazelnut, and some other trees. Forest trees usually suffer the most damage, sometimes being completely defoliated; but trees in parks and along town and city streets are occasionally severely injured. The caterpillars are somewhat gregarious and usually defoliate a branch or two before moving to another. If food is plentiful they do not spread rapidly. They may be fairly abundant in one locality for several years while near by they may be practically unknown.

Description. The moth is bright reddish-yellow in color. The forewings have numerous tiny dark spots and a single small but distinct white spot near the forward edge. The female has a wingspread of about 2½ inches. The male is smaller (about 1½ inches) and slightly darker in color.

The eggs are round, about 1/25 inch in diameter, somewhat flattened, and may vary from clear white to dull coral red. They are laid in large irregular masses on the under side of the leaves.

The newly hatched caterpillar is pale yellow and its large head and legs are black. Two stiff black horns arise from the top of the second body segment just back of the head. Pale bristles are present on the remaining body segments. The mature caterpillar is about 2 inches long and black in color, with eight orange-yellow stripes on the back and sides. The body has many short, sharp spines; and two black, slightly curved horns about ¼ inch long arise from the top of the second body segment.

The pupa is a dark brown, rough, spined object, about 1 inch long and is enclosed in an earthen cell about 3 or 4 inches below the surface of the soil.

Life History. The moths appear about the second week in June and begin laying their eggs in large irregular clusters on the under side of the leaves. There are usually from 200 to 300 eggs in a single cluster but 500 or more may be found. The egg-laying period may last almost a month. The eggs hatch in about a week or 10 days. The tiny young caterpillars begin to feed gregariously on both surfaces of the leaves, consuming all except the network of veins. Later the older caterpillars may eat all but the main vein. They usually defoliate a branch or a tree before moving on to another. They molt five times but, because of the length of the egg-laying period, caterpillars of almost all stages may be found together on a single tree during the summer. By early fall most of the larvae are mature, and about the second or third week in September may be found crawling to the ground where they burrow 3 or 4 inches beneath the surface and construct a simple earthen cell in which they transform to the pupal stage and pass the winter. There is one generation a year in the northern part of the insect's range but in the southern part there may be two.

Control. When but a few branches are infested and they can be reached, the clusters of caterpillars may be collected and destroyed when young. For larger infestations a thorough application of lead arsenate, used in the proportion of 4 pounds of the powder to 100 gallons of water with the addition of 2 pounds of flour or 1 pound of calcium caseinate, is recommended. This spray should be applied as soon as the young caterpillars begin to appear.

Bailey, H. L. Vt. Dept. of Agr. Bul. 35:27. No date.
Felt, E. P. N. Y. State Mus. Mem. 8(1):306-310. 1905.
Houser, J. S. Ohio Agr. Exp. Sta. Bul. 332:249-251. 1918.
Lintner, J. A. N. Y. State Ent. Rpt. 5:192-200. 1889.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:57. 1933.
Packard, A. S. Fifth Rpt. U. S. Ent. Comm., pp. 124-125. 1890.

The two following species are closely related to the orange-striped oak worm and may possibly be confused with it so a brief account of them is given.

Spiny Oak Worm

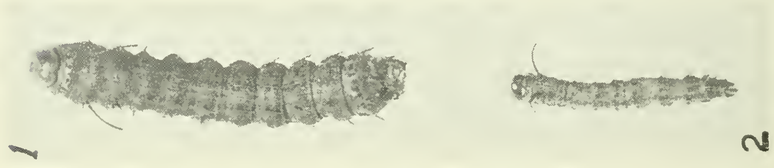
Anisota stigma F.

This species is rare in the northern United States, but it often becomes as injurious in the South as the closely related orange-striped oak worm, *Anisota senatoria*, in the North. It has been reported as feeding on oak in September.

The moths resemble those of *A. senatoria* but are more densely flecked with dark spots. The mature caterpillar, which is about 2 inches long, is bright tawny- or orange-colored with dark, inconspicuous stripes along the back and sides and speckled with numerous tiny raised white dots. In addition to the two long spines on the back of the second body segment, the third and following body segments, unlike the other species of *Anisota* mentioned, have quite long, slightly branched spines instead of short ones.

If an outbreak occurs, an arsenical spray such as that recommended for *A. senatoria*, is effective.

Felt, E. P. N. Y. State Mus. Mem. 8(2):527. 1906.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:57. 1933.
Packard, A. S. Fifth Rpt. U. S. Ent. Comm., pp. 125-126. 1890.



1. **Spiny Oak Worm,** *Anisota stigma.* (Note long barbed spines along body.) Actual size.
2. **Rosy-striped Oak Worm,** *Anisota virginiensis.* (Note short spines along body.) Actual size.

Brown Anisota or Rosy-striped Oak Worm

Anisota virginiensis Drury

The range of this species is believed to be roughly most of the United States east of the Mississippi River. Full-grown caterpillars are observed in greatest numbers in late September. Although the insect is primarily a pest of oak, it is also found on hazelnut and chestnut.

The female moth is brownish-red, has a wingspread of about 1½ inches, a small but distinct white spot on each front wing and an irregular darker line running parallel with the margin of both front and hind wings. The male is somewhat smaller than the female.

The mature caterpillar is about 1½ inches long, and uniform brown with tiny raised dots of pale yellow and regular rows of short, sharp, black spines. Two spines just back of the head on the second body segment are conspicuously longer than the rest and are slightly curved. The striping is not conspicuous.

If an outbreak occurs, an arsenical spray such as that recommended for *A. senatoria* will control it.

Bailey, H. L. Vt. Dept. of Agr. Bul. 35:25. No date.
Houser, J. S. Ohio Agr. Exp. Sta. Bul. 332:251-252. 1918.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:56-57. 1933.

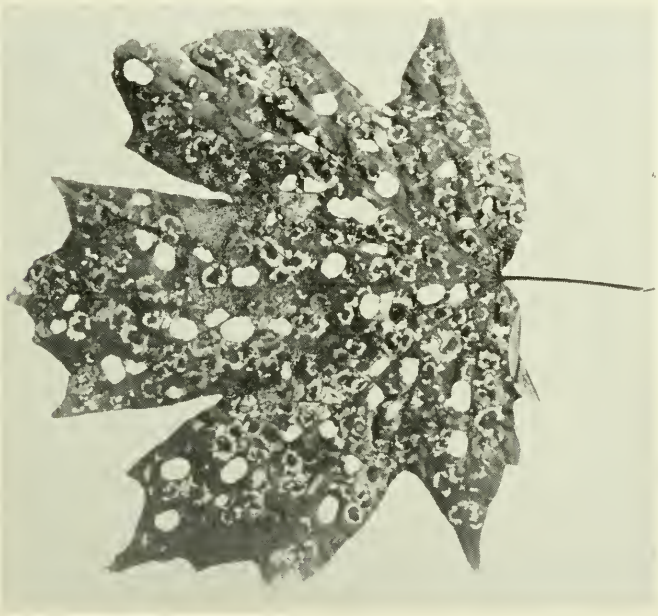
Maple Leaf Cutter

Paraclemensia acerifoliella Fitch

This insect is present in northeastern United States and Canada. It attacks the foliage of sugar maple and may also attack near-by beech trees. Severe defoliation occasionally takes place.

Description. The moth has long, narrow, pointed wings with a spread of about ½ inch. The forewings are steel blue; the hind wings, smoky-brown with purplish reflections. On the head there is a dense tuft of bright orange-yellow hairs.

The mature caterpillar is almost ¼ inch long, slender, cylindrical, flattened, with the body plainly segmented. The head, three succeeding body segments, and an interrupted broad stripe along the back are pale rusty-brown in color. The rest of the body is a dull white.



A Maple Leaf Injured by Maple Leaf Cutters.
Courtesy, N. Y. State College of Agr.

Life History. In the spring the moths deposit their eggs in the leaves. The tiny caterpillar which appears in a few days constructs a small mine between the two leaf surfaces. Then it cuts from a section of leaf a round case in which it lives for the rest of its larval and pupal life. The caterpillar attaches this case to a leaf and feeds on the tissues around the edge of the case, skeletonizing a ringlike area. It then moves with its case to another spot and continues feeding. The centers of these ringlike areas often fall out, leaving holes about ½ inch in diameter in the leaves. This feeding period ends in September when the caterpillars mature. They then descend to the ground, transform to pupae inside the cases, and hibernate below the surface litter. In the spring they transform to moths and emerge.

Control. Raking and burning the leaf litter in the autumn after all the leaves have fallen should kill many of the hibernating pupae.

Spraying the foliage with 4 pounds of lead arsenate to 100 gallons of water is recommended when serious defoliation is threatened.

Bailey, H. L. Vt. Dept. Agr. Bul. 35:34-35. No date.
Felt, E. P. N. Y. State Mus. Mem. 8(2):540. 1906.
Herrick, G. W. Cornell Ext. Bul. 417. 1923.
Packard, A. S. Fifth Rpt. U. S. Ent. Comm. pp. 408-409. 1890.
Swaine, J. M., and Hutchings, C. B. Can. Dept. Agr. Bul. 63, N. S.:11-12. 1926.

Norway Maple Nepticula

Nepticula sericopeza Zeller.

This European moth, now known to be present in parts of northeastern United States, was first found here in 1928. The larvae occasionally tunnel in the petioles, or leaf stems, of the Norway maple, causing the affected leaves to drop about June. This injury, however, is limited to trees which are not producing seed at the time, because the normal habit of the insect is to attack the keys, or winged maple seeds.

There is little about the fallen leaf to suggest the cause of its dropping, but the lower part of an affected leaf stem next to the twig is slightly enlarged and shows a somewhat characteristic, variable, sooty black discoloration for a distance of about ½ inch. At a point almost exactly ½ inch from the base of the leaf stem there is a white, elevated, oval speck.

The seeds, however, are usually preferred. There is a sooty discoloration along the suture between the two seeds. A white spot is also present. Burrows present in the thickened parts of the seeds are partly filled with somewhat characteristic rust-red borings, or castings. Although this insect is not considered destructive, yet it may cause a heavy leaf fall on trees failing to produce seeds.

Life History. The insect hibernates in a flattened, oval, pale orange-yellow cocoon about 3/16 inch long, usually on the bark but occasionally on the fallen keys. Toward the latter part of May or early June the moths emerge and lay their eggs on the developing seeds. The somewhat pale yellowish-green larvae mine in them. Cocoons of the next generation are commonly found in early July on the seeds and leaves. The moths emerge within a week. There are two, and perhaps three, generations a year.

Control. A sticky spray composed of ½ pint of 40 percent nicotine sulfate, 3 pounds of soap, and 2 quarts of molasses to 40 gallons of water is recommended, and should be applied toward the latter part of May, to kill the moths which have emerged and prevent others from emerging from the cocoons.

Felt and Bromley have recommended a dormant application of a miscible oil to destroy the cocoons.[1] Oil sprays should not be applied during freezing weather or when freezing temperatures are apt to occur soon after the application. The spray should be mixed according to the manufacturer's directions.

Felt, E. P., and Bromley, S. W. Jour. Econ. Ent. 23(1):137-142. 1930.
Felt, E. P., and Bromley, S. W. Proc. Ent. Soc. Wash. 32:146-149. 1930.
Felt, E. P., and Bromley, S. W. Jour. Econ. Ent. 24(1):157-159. 1931.
Felt, E. P. Proc. Eighth Nat. Shade Tree Conference, p. 80. 1932.
Felt, E. P., and Bromley, S. W. Bartlett Tree Res. Bul. 2:14-15. 1937.

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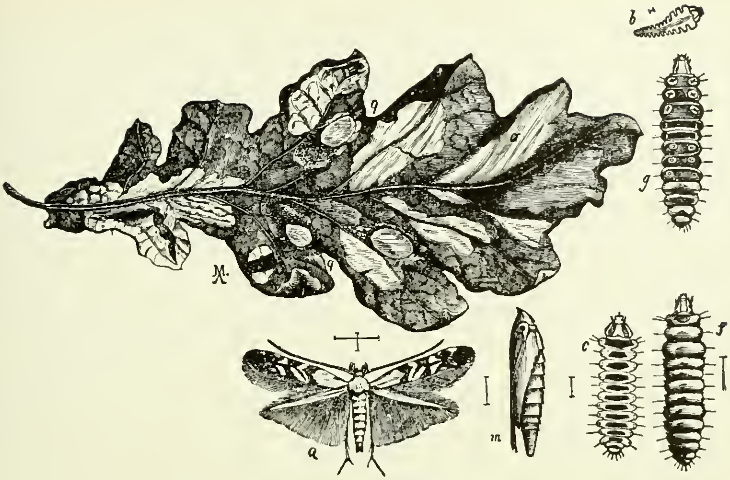
[1] Felt and Bromley report that this treatment is safe on Norway maple. It is not safe on other species of maple.



White Blotch Oak Leaf Miner

a. Mine in leaf.
b. Young caterpillar.
c. Full-grown caterpillar, flat form.
f. Full-grown caterpillar, round form. Top view.
g. Full-grown caterpillar, round form. Bottom view.
m. Pupa.
q. Cocoon.
Q. Adult moth.

Courtesy, Bur. Ent. and Plant Quarantine, U. S. Dept. Agr.

White Blotch Oak Leaf Miner

Lithocolletis hamadryadella Clemens

Several species of leaf-mining insects attack the foliage of oak. One of the most prominent is the white blotch oak leaf miner which is commonly found throughout the Atlantic States.

Each grub, or tiny caterpillar, makes a whitish, blotch-like mine in the upper surface of a leaf. Many grubs may attack a single leaf. There are several generations a year, five having been reported in the vicinity of Washington, D. C., but there are probably fewer farther north. Pupation takes place in the leaf mine. The grubs pass the winter in the leaves on the ground.

Description. The adult is a tiny moth with a wingspread of about ¼ inch. The forewings are white crossed with three broad, irregular, bronze bands, each of which is bordered with black on the inner side. The hind wings are silvery with a broad fringe of hairs.

The body of the young grub is flat, broad in front, and tapering to a point in the rear. The full-grown grub is cylindrical and about 1/5 inch long.

The pupa is dark brown and has a toothed crest on its head. It is covered by a small, round, almost transparent sheet of white silk which is stretched over the floor of the leaf mine.

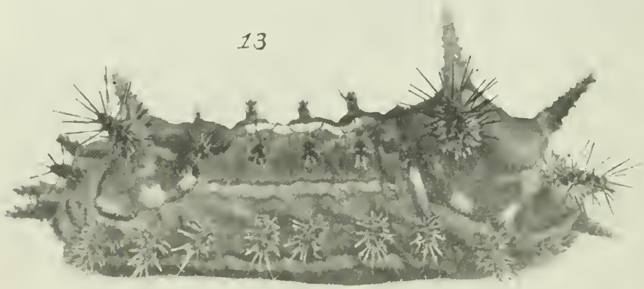
Control. It is recommended that the fallen leaves containing the overwintering grubs be raked up and burned in late fall or before the moths emerge in early spring.

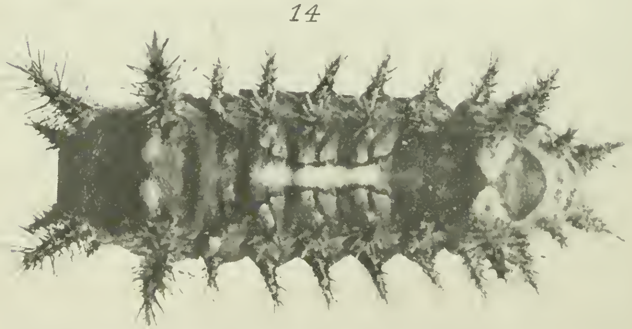
Comstock, J. H. Introduction to Entomology, pp. 618-619. 1933.
Felt, E. P. N. Y. State Mus. Mem. 8(2):532-533. 1906.

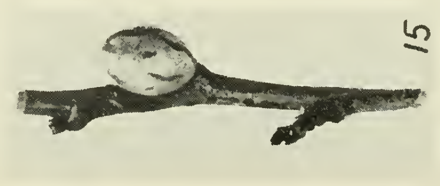
Oriental Moth

Cnidocampa flavescens Walk.

Cocoons of this moth, which is native to the Orient, were first found in the vicinity of Boston in 1906. Since then it has spread slowly into the surrounding area of eastern Massachusetts. The larva, which is one of the slug caterpillars, feeds on the foliage of several trees. Norway maple, sycamore maple, buckthorn, black birch, wild and cultivated cherry, apple, pear, and plum are most severely injured. When the caterpillars are abundant, less favored hosts such as oak, other maples, poplar, willow, honey locust, hickory, and hackberry are attacked.







Oriental Moth

13. Caterpillar, side view. Greatly enlarged.
14. Caterpillar, top view. Greatly enlarged.
15. Cocoon of the oriental moth on a twig. Actual size.

Figs. 13 and 14, Courtesy, American Entomological Society.

The young caterpillars feed on the lower leaf surface, eating small patches of green tissue. As they grow older they devour all the leaf tissue except the larger veins.

Description. The moth has a wingspread of about 1¼ to 1½ inches. The fore part of the body (the thorax) and the inner parts of the wings are light yellow. The rest of the body and wings are a light reddish-brown. The fringes of the wings are a darker brown.

The eggs are oval, flattened, 1/16 inch long, and usually laid singly on the lower surface of the leaves.

The young caterpillars are creamy-white and semitransparent. As they grow older they take on a greater variety of coloring and have markings of yellow, blue, green, and purple. They have numerous hornlike projections covered with long, brittle spines, the longer ones being at the extremities.

The cocoons are ½ inch long, broadly elliptical, smooth, very hard, and usually laid in the fork of a limb or twig. They are grayish-brown with white stripes or markings, and somewhat resemble a bird's egg.

Life History. The moths appear from late June through July and live from 7 to 10 days. They lay their eggs, usually singly, on the under side of the leaves. The eggs hatch in about a week. The young caterpillars molt once and then begin to feed on the foliage. Before becoming mature they molt several times, taking on a greater variety of color at each molt. The young caterpillars eat small green patches of leaf tissue; the older ones leave only the leaf veins. In September or early October the mature caterpillar spins a very hard cocoon in which to pass the winter. Transformation to the pupal stage takes place the following spring. There is only one generation a year.

Control. The young caterpillars which usually appear from late July to mid-August may be satisfactorily controlled by spraying with lead arsenate. This should be used in the proportion of 3 pounds to 100 gallons of water, with ¾ pint of fish oil or raw linseed oil added as a sticker. After August 15 when most of the caterpillars are about half grown and are more resistant to the spray, 4 pounds of lead arsenate to 100 gallons of water plus 1 pint of either oil should be used.

If the plants to be sprayed are near houses or other structures where oil cannot be used, omit the oil and add 1 more pound of lead arsenate to each spray.

On low-growing plants the cocoons may be collected and destroyed.

Fernald, H. T. Hatch Exp. Sta. Mass. Agr. Col. Bul. 114. 1907.
Fernald, H. T., and Summers, J. N. Ent. News 18(8):321-327. 1907.
Collins, C. W. Jour. Econ. Ent. 26(1):54-57. 1933.

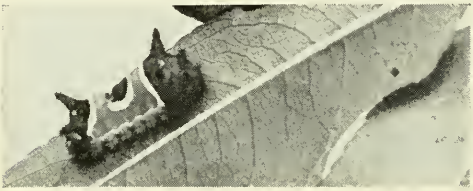
Slug Caterpillars

There are several species of slug caterpillars which occasionally attract attention because of their striking appearance. These include the hag moth caterpillar, *Phobetron pithecium* S. & A.; the saddleback caterpillar, *Sibine stimulea* Clem.; the skiff caterpillar, *Prolimacodes badia* Wlk., and two other slug caterpillars, *Euclea intermina* Boisd., and *Euclea delphinii* Boisd. Some of these are found on a variety of deciduous host plants in midsummer, but they rarely occur in sufficient numbers to be regarded as anything more than natural curiosities.

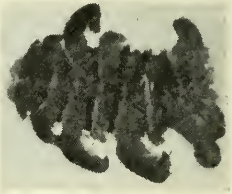
Description. The body of these caterpillars is short and thick, in several species approaching an oval form. The body markings and structures vary considerably in the different species and are often very striking. Although the caterpillars have three pairs of very small legs, they have the appearance of being legless. Along the under side of the body is a series of fleshy elevations or sucking disks which serve for legs. When in motion the larvae glide along in a characteristic fashion, the lower surface of the body being pressed close to the object over which they move. Several species have spines which upon contact with the skin, cause severe irritation.

When full grown, a caterpillar spins a dense, egg-shaped or round cocoon of brown silk, usually between leaves. At one end of the cocoon is a cap which the moth pushes aside when it emerges.

The moths are medium to small in size and have stout bodies. The several species vary greatly in appearance.



Saddleback Caterpillar on Leaf.
Courtesy, Robert L. Coffin.



Larva of Hag Moth.
Greatly enlarged.

Control. Whenever these caterpillars become annoying they may be controlled by spraying the foliage with lead arsenate at the rate of 4 pounds to 100 gallons of water, with 2 pounds of flour or 1 pound of calcium caseinate added to increase adhesiveness.

Britton, W. E. Conn. State Ent. Rpt. 30:462. 1930.
Comstock, J. H. Introduction to Entomology, pp. 608-610. 1933.
Felt, E. P. N. Y. State Mus. Mem. 8(2):527-529. 1906.
Harris, T. W. Insects Injurious to Vegetation, pp. 419-422. 1862.
Packard, A. S. Fifth Rpt. U. S. Ent. Comm. pp. 143-148. 1890.

Red-Humped Caterpillar

Schizura concinna S. & A.

This insect is distributed over practically the entire United States and parts of Canada. It is commonly considered to be an orchard pest but it also attacks the foliage of a number of forest and shade trees including birch, willow, aspen, butternut, walnut, and others. The caterpillars, which appear in midsummer, feed in colonies, especially when young, and may defoliate a single branch or an entire tree.

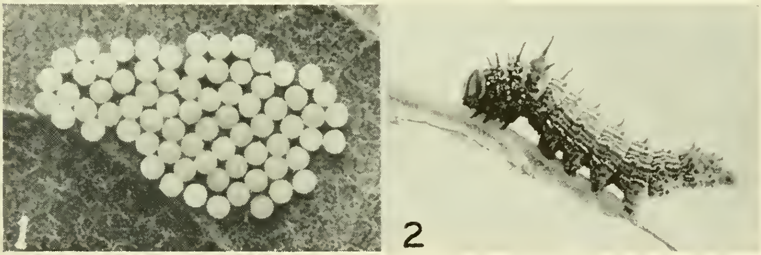
Description. The moth is colored an inconspicuous grayish-brown. The female has a wingspread of about 1½ inches; the male slightly less.

The eggs are white, almost round, and occur in masses of about 100 on the under side of leaves.

The full-grown caterpillar is about 1 inch or slightly over in length, is striped with narrow black and yellow lines running lengthwise along the body, and has a double row of black spines along the back. The body tapers slightly toward the rear end. The head and a conspicuous hump on the fourth body segment are a bright red.

The cocoon on the surface of the ground is of loosely woven silk and into it particles of earth and rubbish are glued so that it closely resembles its surroundings.

Life History. The moths appear about the last of June or early in July. The females soon deposit their eggs in groups of about 50 to 100 on the under side of the leaves. Upon hatching in early August, the young caterpillars feed on the under side of the leaves and skeletonize them. Later they eat the entire leaf except the large veins and may also attack the tender bark on new shoots. Entire branches and sometimes whole trees may be defoliated. The caterpillars feed in groups especially when young, but maintain this habit to a certain extent throughout their life. When not feeding they may be found clustered on the trunk or branches with the rear part of the body slightly elevated. They reach maturity in late August and September, at which time they descend to the ground and construct a loose silken cocoon under rubbish or among loose particles of earth. They usually overwinter as caterpillars in this cocoon, transform to pupae the following spring, and later emerge as moths. There is only one generation a year in most of northern United States and Canada but farther south there are two.



Red-Humped Caterpillar.

1. Egg mass on surface of leaf. Greatly enlarged. Courtesy, N. H. Agr. Expt. Station.
2. Mature caterpillar. 1½×. Courtesy, Conn. Agr. Expt. Station.

Control. The insect can be controlled by a thorough application of lead arsenate mixed in the proportion of 4 pounds to 100 gallons of water with 2 pounds of flour or 1 pound of calcium caseinate added as a sticker. It should be applied when the young caterpillars first begin to appear in early August.

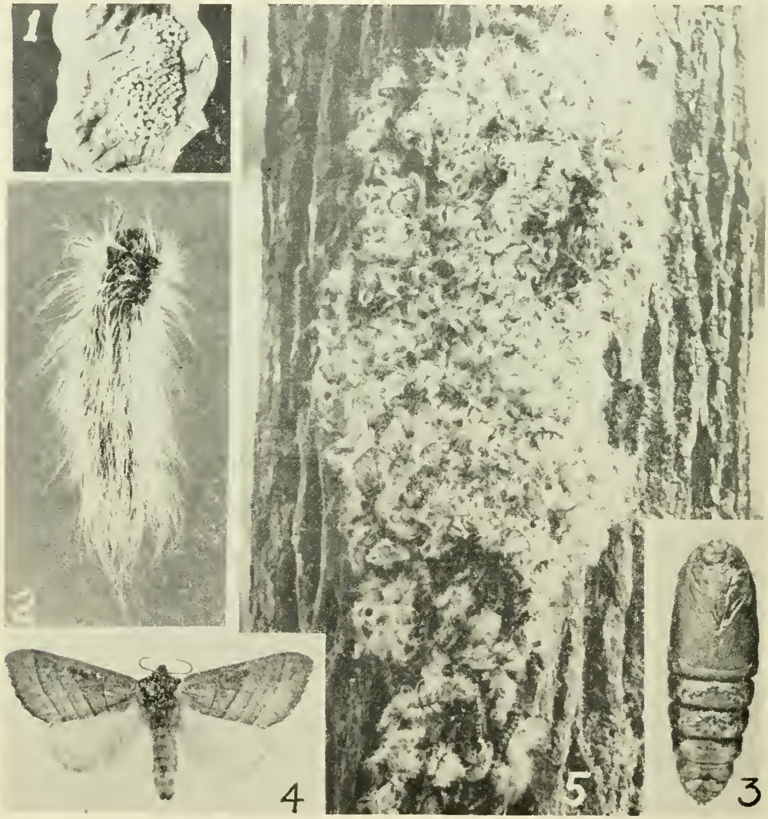
In the case of a light infestation on small trees, the colonies of caterpillars may be collected by hand and destroyed when they are young and are clustered on the foliage of a single branch or twig.

Essig, E. O., and Hoskins, W. M. Calif. Agr. Ext. Serv. Circ. 87:75. 1934.
Houser, J. S. Ohio Agr. Exp. Sta. Bul. 332:254-256. 1918.
Lounsbury, C. P. Hatch Exp. Sta. Mass. Agr. Col. Bul. 28:17-19. 1895.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:23-24. 1933.
Sanderson. E. D. N. H. Agr. Exp. Sta. Bul. 139:216-218. 1908.

Walnut Caterpillar

Datana integerrima G. & A.

This native moth is known to be present from Maine to Florida and west to Kansas. The caterpillars seem to prefer the foliage of the black walnut but also attack pecan, butternut, English walnut, Japanese walnut, and hickory, and have occasionally been reported on other trees. The feeding usually occurs about midsummer. The caterpillars feed in clusters, often devouring all the leaves on one limb before moving on to another. In severe attacks the whole tree may be defoliated. Isolated trees or trees in small groups are more liable to be injured than groves of the preferred host, or than trees located in woodlands. Oftentimes when the caterpillars are disturbed they will characteristically raise both ends of the body suddenly and remain motionless for a minute or so.



Walnut Caterpillar

1. Egg mass on leaf. Actual size.
2. Mature caterpillar. Slightly enlarged.
3. Pupa 2×.
4. Adult female moth. Actual size.
5. Cluster of cast skins on tree trunk.

Courtesy, Conn. Agr. Expt. Station.

Description. The moths are heavy-bodied, with a wingspread of nearly 2 inches. The forewings are buff-colored, with darker lines running irregularly across them. The hind wings are lighter in color and do not have the cross lines.

The eggs are seldom observed. They are deposited in masses of 300 or more on the under side of the leaves. The individual eggs are less than 1/35 inch in diameter, elongate, and round, approaching cylindric with somewhat flattened apex. The color is dull white; the surface is somewhat roughened and has regular markings.

The newly hatched caterpillars have black heads and brick-red bodies with faint stripes. As they become older, the brick-red color deepens, the lines become more distinct, and long sparse hairs appear. The mature caterpillar is a little over 2 inches long. The body is black, very indistinctly lined, and covered with a considerable number of long white or grayish-white, frowsy hairs.

The pupae are found below the surface of the ground near their host trees. They are a little over ½ inch long, hard, and dark brown in color.

Life History. The moths usually are abroad in July. Soon after emerging they lay their eggs in masses of about 300 on the under side of the leaves. These eggs hatch in a week or ten days, probably in late July or early August in this region. The young caterpillars feed in clusters on the foliage, at first skeletonizing the under side but later consuming the entire surface of the leaves. At certain times during this feeding period they congregate in masses on the trunk or larger branches and shed their skins, after which they soon return to the foliage to feed again. The masses of hairy, cast-off skins remain on the tree for a while, presenting an unsightly appearance. The caterpillars retain the gregarious habit until fall approaches when they are almost mature and ready to pupate, at which time they wander about for a few days. They then go to the ground, burrow beneath the surface, and transform to naked pupae, in which stage they pass the winter. Transformation to the adult stage takes place the next season. There is only one generation a year in this vicinity; farther south there may be two or three.

Control. The caterpillars may be destroyed on valuable shade trees by spraying the foliage thoroughly with lead arsenate in the proportion of 4 pounds to 100 gallons of water with 2 pounds of flour or 1 pound of calcium caseinate as a sticker. This should be applied when the caterpillars begin to feed.

The caterpillars feed gregariously, often on one limb. If the infested branch is a small one, it can be removed without injury to the tree and the caterpillars destroyed.

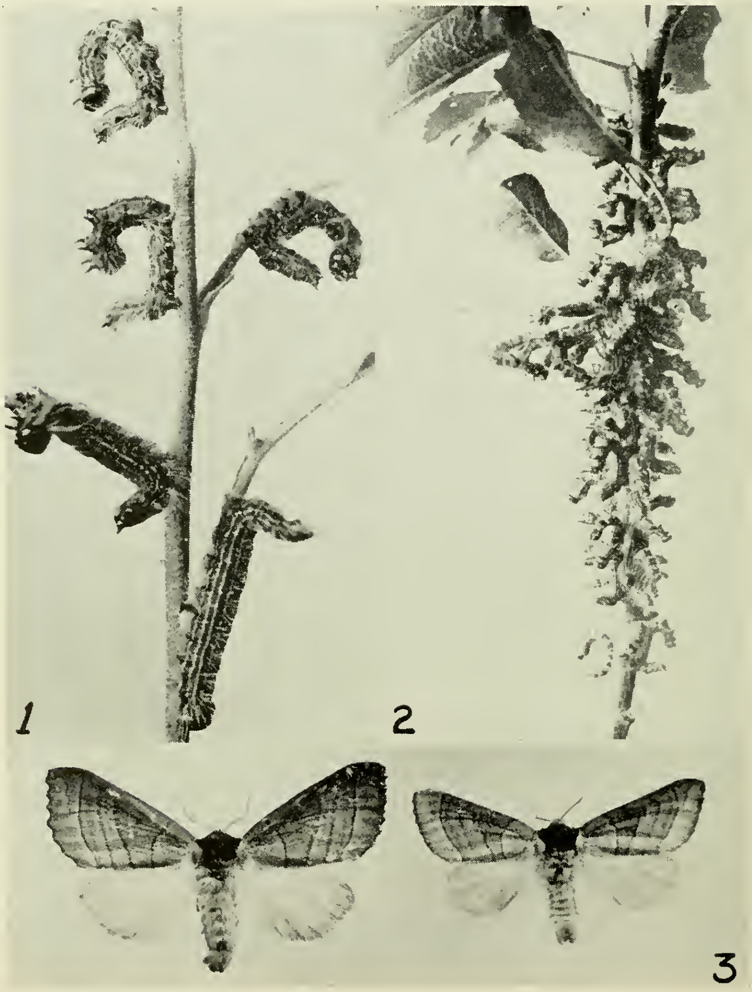
Sometimes the clusters of caterpillars which are shedding their skins on the trunk or limbs may be crushed or otherwise destroyed. If this is not done until the older caterpillars are shedding their skins, some injury to the foliage will have already occurred.

Baerg, W. J. Ark. Agr. Exp. Sta. Bul. 224:9-15, 25. 1928.
Britton, W. E. Conn. State Ent. Rpt. 17:326-328. 1918.
Felt, E. P. N. Y. State Mus. Mem. 8(1):303-305. 1905.
Houser, J. S. Ohio Agr. Exp. Sta. Bul. 332:226-229. 1918.

Yellow-Necked Caterpillar

Datana ministra Drury

This insect is widely distributed in the United States. It is common in the northeastern United States and is also present on the Pacific Coast. Although it is primarily an orchard pest, the caterpillar occasionally causes considerable injury to the foliage of some shade and ornamental trees. Its attack occurs from midsummer to late summer. This insect, like the closely related walnut caterpillar, *Datana integerrima*, and others of the genus *Datana*, has the peculiar habit of elevating both ends of the body when disturbed.



Yellow-Necked Caterpillar

1. Caterpillars on apple twig. Actual size.
2. A characteristic cluster of caterpillars. Reduced. Courtesy, N. H. Agr. Expt. Station.
3. Adult female and male moths.

Figs. 1 and 3, Courtesy, Conn. Agr. Expt. Station.

Description. The moths closely resemble those of the walnut caterpillar, and it is difficult to distinguish one species from the other.

The eggs are found in masses of about 100 or more on the under side of the leaves. They are very small, oval, and white.

The mature caterpillars are about 2 inches long. The head is jet black. The body segment just behind it (the prothorax) is a bright orange-yellow, a character which gives the insect its common name. The body is striped lengthwise with alternate black and yellow stripes and is thinly covered with long, soft, white hairs but does not have the distinctly hairy appearance of the walnut caterpillar. Consequently when it molts it does not leave hairy patches on the tree where molting occurs.

The pupae are about ½ inch long and dark brown in color.

Life History. The moths appear in early summer from mid-June through July, and lay their eggs in clusters of 100 or more on the under side of the leaves. The eggs hatch from late July through early August, and the caterpillars begin to feed on the foliage. The newly hatched caterpillars skeletonize the lower surface of the leaves, but the older ones devour the entire leaf with the exception of the stem. Like the walnut caterpillars, these also feed gregariously and are often found clustered together in a solid mass on a limb. The caterpillars feed for about a month, maturing from late August into September. When mature they descend to the ground, usually at night, burrow beneath the surface, and transform into pupae without any cocoon. The moths appear the following summer. There is one generation in this section.

Control. Control measures advised for the walnut caterpillar are effective for this insect.

Britton, W. E. Conn. State Ent. Rpt. 17:328-329. 1918.
Felt, E. P. N. Y. State Mus. Mem. 8(2):535-536. 1906.
Houser, J. S. Ohio Agr. Exp. Sta. Bul. 332:229-230. 1918.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:30. 1933.
Ruhmann, M. H. Brit. Columbia Dept. Agr. Ann. Rpt. 29:B37-B39. 1935.
Sanderson, E. D. N. H. Agr. Exp. Sta. Bul. 139:213-215. 1908.

Birch Skeletonizer

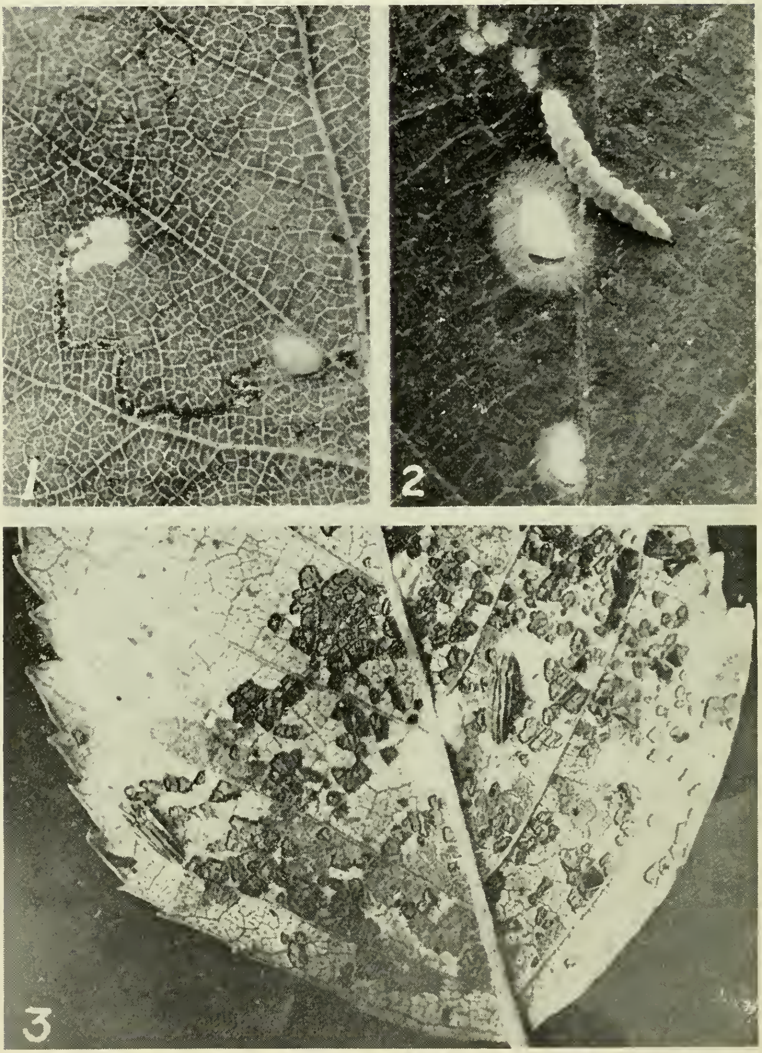
Bucculatrix canadensisella Chambers

This moth has been found in northern United States and in Canada. In the United States it occurs from Maine to Minnesota and south to North Carolina; in Canada, from New Brunswick west to British Columbia and probably as far north as the Yukon.

The larvae, or caterpillars, are restricted to the birches and possibly the alder, *Alnus incana.* The host birches include gray birch, *Betula populifolia;* white or paper birch, *B. papyrifera;* yellow birch, *B. lutea*; black birch, *B. lenta;* and the European white birch, *B. alba*, the varieties of the last being known as the cutleaf or weeping birch.

Since about 1890 severe outbreaks have occurred at intervals of about ten years, when large areas of birches have been skeletonized. Between these outbreaks were years of comparative scarcity. This insect is considered to be chiefly a pest of woodland trees but when abundant has been known to attack shade trees. The caterpillars feed in late summer on the lower surface of the leaves, preferably the older ones, skeletonizing them. The affected leaves die and drop from the tree. The greatest amount of feeding occurs during late August and September at which time the trees have passed through the most active season and thus are not so seriously injured as they would be by a similar attack earlier in the summer or in the spring.

Description. The adult is a very tiny moth, with a wingspread of only 3/8 inch. The general color is a bright brown with transversely diagonal, silvery-white bars on the forewings. The wings, especially the hind pair, have broad fringes of hair.



Birch Skeletonizer

1. Vacant mine of larva in birch leaf. 4×.
2. Fully grown larva with first (lower) and second (upper) vacant molting webs on birch leaf. 4×. Figs. 1 and 2. Courtesy, Conn. Agr. Expt. Station.
3. Birch leaf skeletonized by larvae, showing webs and the ribbed cocoons. Enlarged. Courtesy, Mich. Agr. Expt. Station.

The eggs are laid singly and scattered over the leaf. They are translucent white when first laid but soon become quite opaque, are flatly ovoid in shape and about 1/100 inch in diameter. They are encircled by an adhesive substance which attaches them to the leaf surface.

The newly hatched larva, or caterpillar, which mines in the tissues of the leaf, is very tiny. It is translucent, flattened, and legless — a typical leaf-mining type. The mature caterpillar which feeds externally is about ¼ inch long. The head is brown, and the body yellowish-green with hairs projecting from white tubercles.

The pupa is spindle-shaped, about 1/8 inch long, brown in color and shows many of the adult structures.

Life History. The moths begin to appear about the last of June, become very abundant before the middle of July, and disappear by about the end of that month. Several days after appearing they begin to lay their eggs, apparently at night. Sixty or more eggs may be laid by one female. The eggs are laid singly on either side of a leaf and on any part of the surface although there is some preference for a position next to the midrib or other prominent vein. The eggs hatch in about 2 weeks. The young caterpillar bores through the bottom of the egg into the leaf where it constructs a small, blotch-like mine which soon becomes linear and winding with slightly enlarged ends. It tends to avoid chewing through the large veins. Most of the completed mines are about ¾ inch long. When the insect is abundant, 30 or more mines may be found in a single leaf. The caterpillars molt twice in the mine. The time spent in the mine varies greatly but under normal conditions is about 24 to 31 days. Caterpillars were found in their mines until mid-September. To emerge from the mine a caterpillar cuts a crescent-shaped opening in the lower surface of the leaf, and soon afterwards it constructs on the surface of the leaf a small, oval, silken web under which it molts. Upon leaving this web it feeds from 1 to 9 days on the lower leaf surface, skeletonizing it. It then constructs another web, molts again, emerges, and continues feeding, this time much more extensively. The injury to the foliage becomes most noticeable at this time, usually during late August and through most of September. Severely injured leaves die and fall to the ground. The caterpillars feed for several days, then drop to the ground on silken threads and spin their cocoons under various objects in the debris on the ground. Pupation soon occurs and the insect passes the winter in that stage. There is one generation a year.

Control. To control this insect, spray both sides of the foliage thoroughly with lead arsenate at the rate of 4 pounds to 100 gallons of water, with 2 pounds of flour or 1 pound of calcium caseinate added as a sticker. This spray should be applied when the caterpillars begin to feed externally on the leaves, which is usually a little before or about the middle of August.

Friend, R. B. Conn. Agr. Exp. Sta. Bul. 288:395-486. 1927.

Elm Casebearer

Coleophora limosipennella Dup.

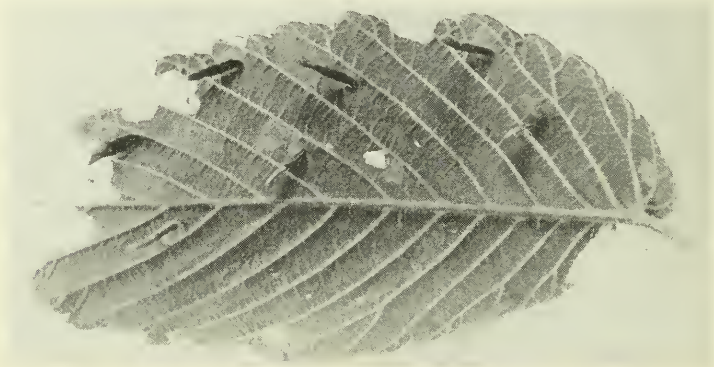
This peculiar insect, which is found in the eastern United States, was evidently introduced from Europe, the first specimens having been reported in 1901 from the vicinity of New York City. In this country only elm seems to be attacked, English and Scotch elms evidently being preferred. In Europe birch and alder are also attacked.

The caterpillars work at first as leaf miners but soon become casebearers, in both forms feeding on the inner tissues of the leaves. The areas mined by the casebearers are more or less rectangular in shape, being bounded by the larger veins of the leaf. The cases of these caterpillars stand out at right angles to the leaf surface while the larvae are feeding. This habit of forming cases distinguishes this species from the caterpillars of the elm leaf miner, *Kaliosysphinga ulmi.*

Description. The adult female is a tiny buff-colored and gray-marked moth with a wingspread of about ½ inch.

The eggs are very tiny and are sugar-loaf-shaped, typical of the genus *Coleophora.*

The case for the caterpillar is slender, somewhat flattened at the rear, brown, and about 3/8 inch long. The caterpillar has a light brown head, a dark brown area just behind it on the back, and a hard, dark brown plate on the upper surface at the rear end of the body.



Elm Casebearers on Leaf. Actual size.
Courtesy, Conn. Agr. Expt. Station.

Life History. The partly grown caterpillars pass the winter in a slender, brown case attached to the limbs and branches of a tree. When the leaves appear in the spring, the caterpillars migrate to them carrying their cases with them. They eat in the leaf tissues a small, circular hole about the size of a pinhead and then mine or eat out all the inner tissues they can reach without leaving the case. In July they mature and pupate inside their cases which are firmly attached to the leaves. The moths appear the latter part of July and lay their eggs. Upon hatching, the young caterpillars first work as leaf miners, and probably, like some closely related species, enter the leaf immediately under the egg. Soon, however, they desert their mines and become case bearers. They feed for a time in the fall, then migrate to the branches before the leaves fall. There is one generation a year.

Control. Lead arsenate, at the rate of 4 pounds to 100 gallons of water with 2 pounds of flour or 1 pound of calcium caseinate, applied in the spring when the caterpillars begin to feed, is the treatment usually recommended for this insect. A contact spray which has proved to be satisfactory against a related species is sometimes recommended for the control of this insect and should be applied when the tiny, young caterpillars first desert the leaves and become casebearers. The spray consists of 1 pint of 40 percent nicotine sulfate plus 4 pounds of soap in 100 gallons of water.

Britton, W. E., and Friend, R. B. Conn. Agr. Exp. Sta. Bul. 369:288-289. 1935.
Felt, E. P. N. Y. State Mus. Mem. 8(1):167-168. 1905.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:42. 1933.

In parts of Maine there is a moth known as the birch casebearer, *Coleophora salmani* Heinr., the caterpillars of which for the most part attack the leaves of various birches and speckled alder; but red oak, red maple, hazelnut, trembling aspen, and willow growing near heavily infested birches are sometimes attacked by the mature larvae. Its life history and habits are somewhat similar to those of the related elm casebearer, *Coleophora limosipennella* Dup. It may be distinguished from the birch skeletonizer, *Bucculatrix canadensisella*, and other birch leaf-feeding insects mentioned here, by the presence of the cases on the leaves. It has not yet been reported to occur in Massachusetts.

Gillespie, A. M. Maine Forest Service Bul. 7. 1932.

Peirson, H. B., and Brower, A. E. Maine Forest Service and Maine Hardwood Assoc. Bul. 11. 1936.

Mourning-Cloak Butterfly

Hamadryas antiopa Linn.

This insect, sometimes known as the spiny elm caterpillar, is widely distributed over the North Temperate Zone. It is one of the few butterflies of economic importance. The caterpillars feed in colonies, mainly on elm, willow, poplar, and hackberry, often defoliating a terminal branch here and there or, when abundant, the whole tree.

Description. The butterfly has a wingspread of about 2½ inches. The body is black. The upper wing surfaces are dark reddish-brown with a yellow border finely dotted with dark blue markings. Just inside this yellow border there is a series of bluish spots.

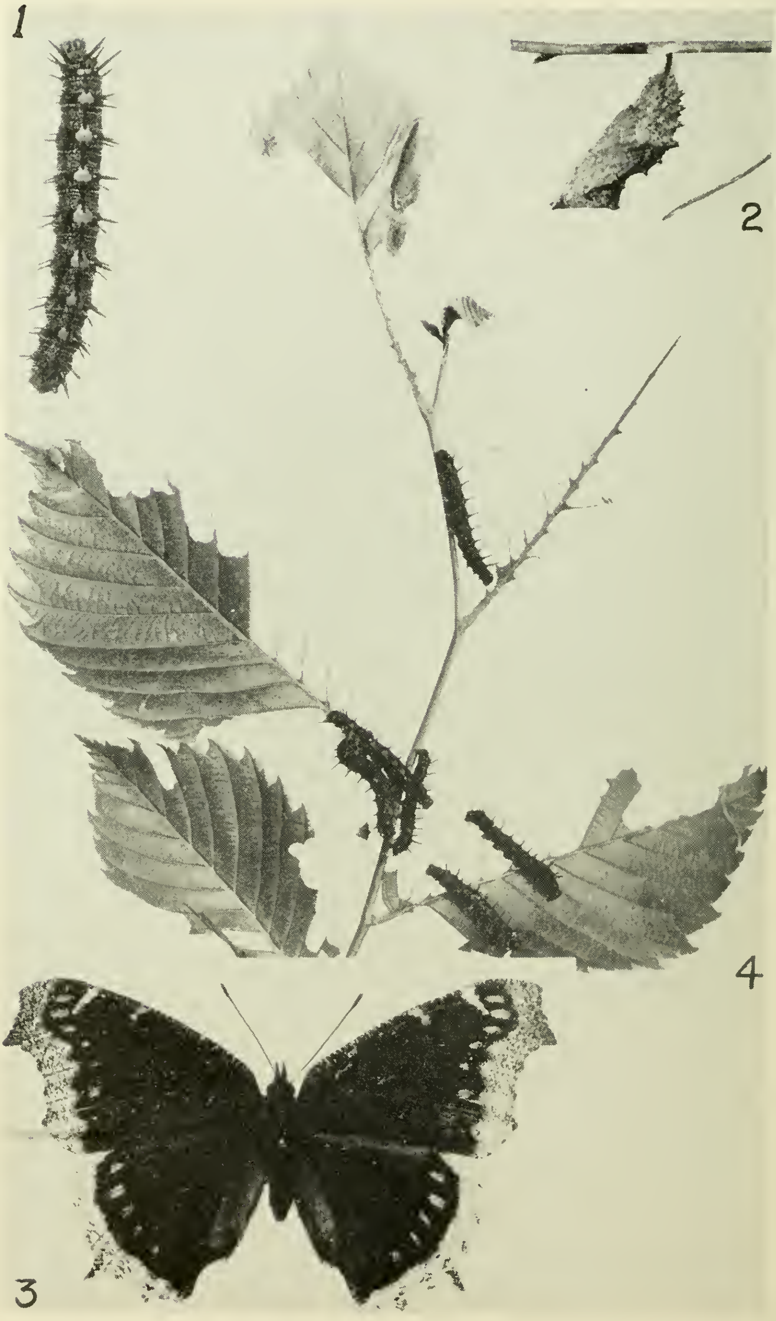
The eggs are irregular in shape, some being 7- or 8-sided, and are laid side by side around twigs in masses which may be 1 or 2 inches in length.

The mature caterpillars are black, the entire body being encircled by successive rings of white dots and covered with numerous large, branched spines. On the top of each body segment there is a red spot. The head is covered with tubercles.

The pupae are pale powder-blue and have a double row of simple spines along one side.

Life History. The butterflies hibernate in sheltered places. On warm days in the early spring they may be seen flying about, and in May they lay their yellowish eggs in naked clusters around small twigs or branches. These hatch in about 2 weeks and the tiny caterpillars feed side by side on the leaves, eating all the leaf tissue except the veins. Whole branches may be defoliated at this time. As the larvae grow older they leave only the large midveins. Toward the latter part of June the caterpillars become mature, stop feeding, scatter, attach themselves to the under side of twigs, branches, or fence rails, and pupate within their last larval skin. In approximately 2 weeks the butterflies emerge from the chrysalids and may be seen on the wing early in July. They soon lay eggs for a second generation, the caterpillars of which feed on the leaves during August. The second generation seldom causes much damage and usually goes unnoticed. The adults go into hibernation in early fall.

Control. When the caterpillars are abundant the usual recommendation is to spray the foliage, in the spring when the spiny caterpillars are still very small, with lead arsenate at the rate of 4 pounds to 100 gallons of water. Two pounds of cheap flour or 1 pound of calcium caseinate may be added to improve the sticking qualities. Sprays applied to elms to control cankerworms or elm leaf beetles will also control this insect.



Mourning-Cloak Butterfly

1. Caterpillar. Actual size.
2. Chrysalid. Actual size.
3. Adult butterfly. Actual size.
4. Leaves injured by caterpillars. Reduced.

If the caterpillars are confined to one or two branches, those branches may be removed and the caterpillars destroyed by crushing or burning, or they may be shaken from the branch and destroyed.

Britton, W. E., and Friend, R. B. Conn. Agr. Exp. Sta. Bul. 369:274. 1935.
Felt, E. P. N. Y. State Mus. Mem. 8(1):158-162. 1905.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:43-44. 1933.

Elm Leaf Beetle

Galerucella xanthomelaena Schr.

The elm leaf beetle, a native of Europe, was first found to be destructive in this country near Baltimore, Maryland, in 1838, having been introduced a few years earlier. At present it is widely distributed across the continent and is the most serious defoliating insect pest of elm in this country. Elms in urban and suburban situations are principally injured, although occasionally trees in strictly rural localities and in swamps are attacked. The English elm, Camperdown elm, American elm, and Scotch elm seem to be preferred, but all species of elm are subject to attack. Injury is more extensive under certain climatic conditions such as protracted dry spells.

Several insects prey upon the elm leaf beetle, and a fungus disease attacks the pupal stage causing high mortality, especially during wet weather.

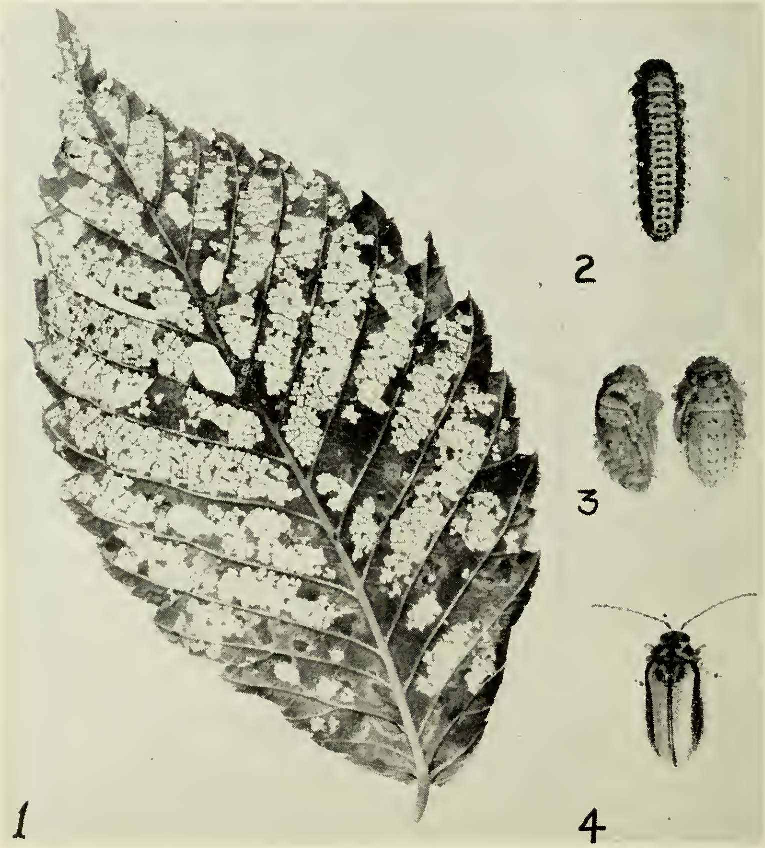
Description. The newly emerged adults are about ¼ inch long and are yellow with a dark stripe along each side of the wing covers and a short, dark spot at the base of each wing cover. The upper side of the thorax just behind the head has a dark median spot and one on each side. The beetles which have overwintered are much darker in color, being brownish-green.

The eggs are deposited on the under side of the leaves in clusters of 3 to 26 or more, usually side by side in irregular rows. They are yellow and bottle-shaped, the broader end being attached to the leaf surface.

The newly hatched larva, or grub, is about 1/20 inch long, the prevailing color is almost black, and the body is covered with tubercles bearing black hairs. As it grows and molts it assumes a yellowish color. The mature grub is about ½ inch long and flatter than the earlier stages. The under side of the body and a broad central stripe on the upper side are bright yellow. A stripe on each side of this central stripe is black as are the head and legs.

The pupa is bright yellow, broadly oval in shape, and about 1/5 inch long. The body is rounded on top and bears dark hairs on tiny dark tubercles. The adult appendages, held rather close to the body, are plainly discernible.

Life History. The beetles hibernate in dry, sheltered places such as protected parts of buildings, barns, cracks and crevices in posts and poles, the under side of loose bark, and similar locations. Occasionally they find their way into dwellings where they are sometimes taken for household pests. They are not known, however, to injure any household articles. The beetles emerge from their shelters when the leaves of elm first unfold in the spring and eat in them oval holes about ¼ inch in diameter. Soon after mating, the females begin to lay their eggs in small clusters on the under side of the leaves. The eggs hatch in about a week. During early June, the tiny black larvae begin to appear and feed on the lower surface of the leaves, eating all the green tissue and leaving only the veins and the upper leaf surface. It is this type of feeding that is so injurious, the earlier feeding of the adults not being important. In early July the larvae become full grown, crawl down or drop from the tree and transform into bright yellow pupae on the ground at the base of the tree, in near-by cracks and crevices, under loose bark, or in bark crevices. In about 10 days the beetles appear. They presently begin feeding but cause no material damage at this time. With the approach of cold weather, the beetles seek shelter and hibernation quarters. One generation a year is usual in Massachusetts. The number of generations produced in a season, however, varies in different localities and even in the same locality may be affected by the earliness or lateness of the season. Two and three generations have been reported from localities farther south on the Atlantic Coast, while in California there may be as many as five.



Elm Leaf Beetle

1. A leaf skeletonized by the grubs. Actual size.
2. Grub. Enlarged.
3. Pupae, bottom and top views. Enlarged.
4. Adult beetle. Enlarged.

Control. The usual recommendation is to spray the trees with lead arsenate as soon as they reach full foliage. The spray should be directed to the under side of the leaves where the larvae feed. During very severe infestations it would be advisable to spray twice. The first application should be made when the leaves are about three-quarters grown while the overwintered adults are still feeding and laying their eggs. A second spray should be applied when the young larvae are appearing, about 3 weeks later, at which time the tree will probably have all its foliage and the entire leaf surface may be poisoned. This is normally in early June. Lead arsenate is recommended in the proportion of 5 pounds to 100 gallons of water with 1¼ pints of fish oil or raw linseed oil added as a sticker.

Because the mature larvae, or grubs, go to the ground to pupate, both grubs and pupae may often be found in clusters near the base of the trees during periods of heavy infestation. These larvae and pupae may be destroyed by pouring hot water or carbon disulfide over them. Care should be taken to see that the material does not come in contact with the trunk or roots of trees or any other cultivated plant which might be injured by such an application. A much safer mixture would be 1 pint of nicotine sulfate with 4 pounds of laundry soap to 100 gallons of water. Occasionally it might be feasible to crush or collect and drop the insects into a can of kerosene and water. Another method falling into this category is the destruction of any groups of hibernating adults which might be found in shelters near infested elms.

It should be remembered, however, that these are merely intended to supplement the all-important spraying measures by helping to reduce the future generation of destructive grubs and beetles and should not be solely depended upon for control.

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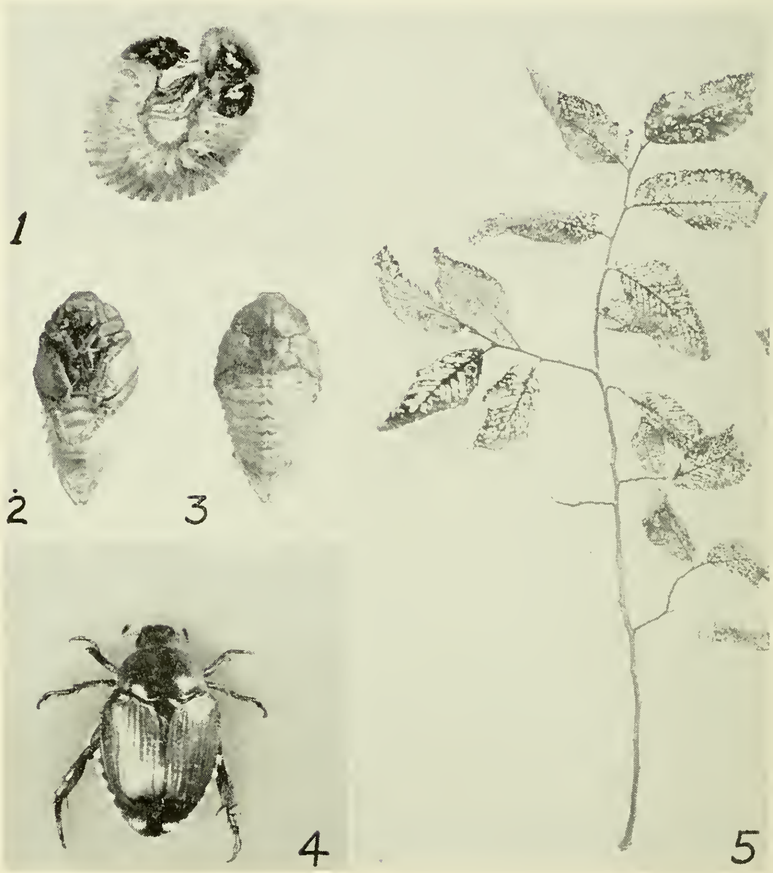
Japanese Beetle

Popillia japonica Newm.

The Japanese beetle is a native of the Orient and was first found in this country near Riverton, N. J., in 1916. Since then the insect has spread rapidly over a large part of New Jersey and adjoining states as well as a considerable portion of southern New England. It has proved to be a very serious pest. The larvae, or grubs, feed on the roots of various plants and grasses. The adults feed on the foliage of numerous fruit and shade trees, shrubs, garden plants, and field crops, and also attack flowers and fruits. In feeding on the foliage they avoid the veins, giving the leaves a skeletonized appearance. Among shade trees they especially prefer elm, chestnut, horsechestnut, linden, and sassafras, but also feed on Norway maple, pin oak, plane trees, Lombardy poplar, willow, and birch. When preferred trees are not available, the beetles may attack the more tender foliage of trees normally not touched. Conifers are seldom attacked. The beetles prefer to feed on the parts of the plants exposed to the direct sunlight, beginning their attack usually on the upper and outer parts of the trees and working downward and inward.

Description. The beetle is approximately ½ inch long, broadly oval in shape, and shiny green in color. The wing covers, which are a coppery brown, do not quite reach to the tip of the abdomen. Just beyond the edge of the wing covers are twelve tufts of hairs which distinguish this beetle from other species which it resembles.



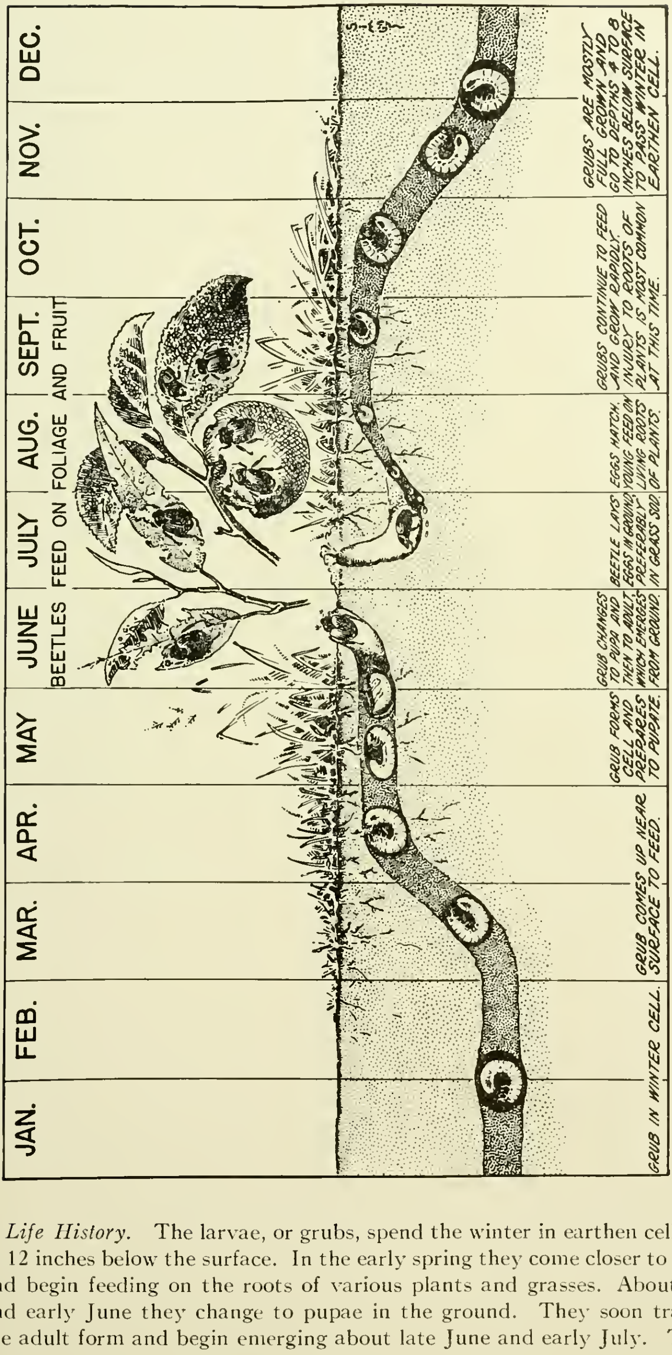
Japanese Beetle

1. Grub. Greatly enlarged.
2 and 3. Pupae, bottom and top views. Greatly enlarged.
4. Adult beetle. Greatly enlarged.
5. Injured elm leaves.
Courtesy, Robert L. Coffin.

The newly deposited eggs are elliptical, translucent, creamy-white, and about 1/16 inch in diameter. After being in the ground a week they swell to twice this size and become almost round.

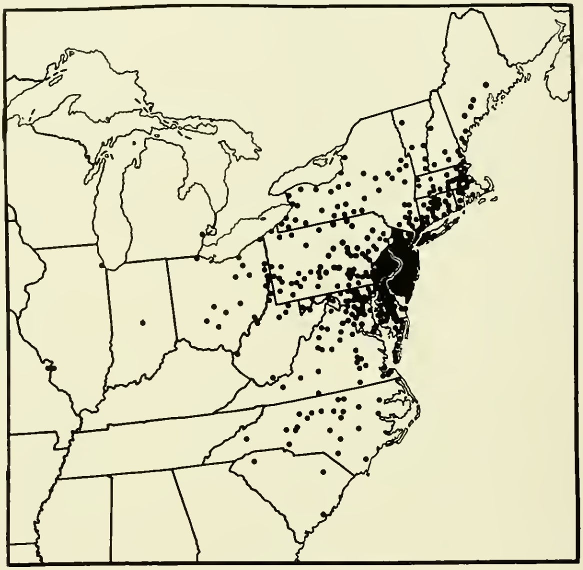
The newly hatched grub is about 1/16 inch long. When mature it is about 1 inch long and creamy-white in color. It is normally curled into a U-shaped position, the posterior portion being broadly rounded and slightly swollen. It resembles the grub of the June beetle but may be distinguished from it by a V-shaped arrangement of spinelike hairs on the hindmost abdominal segment, and by other characters which can only be distinguished by microscopic examination.

The pupa is similar to the grub in color and texture but, having all the adult appendages closely appressed to its sides, has the general form of an adult.


JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
BEETLES FEED ON FOLIAGE AND FRUIT
GRUB IN WINTER CELL.
GRUB COMES UP NEAR SURFACE TO FEED.
GRUB FORMS CELL AND PREPARES TO PUPATE.
GRUB CHANGES TO PUPA AND THEN TO ADULT, WHICH EMERGES FROM GROUND
BEETLE LAYS EGGS IN GROUND, PREFERABLY IN GRASS SOD
EGGS HATCH. YOUNG FEED ON LIVING ROOTS OF PLANTS.
GRUBS CONTINUE TO FEED AND GROW RAPIDLY. INJURY TO ROOTS OF PLANTS IS MOST COMMON AT THIS TIME.
GRUBS ARE MOSTLY FULL GROWN AND GO TO DEPTHS 4 TO 8 INCHES BELOW SURFACE TO PASS WINTER IN EARTHEN CELL.

Diagrammatic Representation of the Seasonal Life Cycle of the Japanese Beetle.
Courtesy, Bur. Ent. and Plant Quarantine, U. S. Dept. Agr.

Life History. The larvae, or grubs, spend the winter in earthen cells from 1½ to 12 inches below the surface. In the early spring they come closer to the surface and begin feeding on the roots of various plants and grasses. About late May and early June they change to pupae in the ground. They soon transform to the adult form and begin emerging about late June and early July. The beetles feed on foliage for a time after emerging, and then mate. The females then begin to lay their eggs in the ground, preferring for the purpose medium moist, loamy soil covered with grass, such as lawns, pastures, and golf fairways and greens. Egg laying continues until about mid-August. One to 4 eggs are deposited, usually at night, in holes 2 to 4 inches deep. The beetles feed during the day. They may be seen feeding on plants until early fall although the peak of the feeding season occurs in late July or early August. The eggs hatch about 2 weeks after they are laid. The larvae then feed on the smaller plant roots. They often grow to be about ¾ to 1 inch long before cold weather. The grubs usually feed in the upper 3 inches of the soil, but as winter approaches they go deeper to hibernate.



POINTS AT WHICH JAPANESE BEETLES HAVE BEEN FOUND UP TO AND INCLUDING THE YEAR 1935.

■ AREA CONTINUOUSLY INFESTED BY NATURAL SPREAD.

▨ LOCALIZED COLONIES OR POINTS OF MINOR OCCURRENCE.

Courtesy, Bur. Ent. and Plant Quarantine, U. S. Dept. Agr.

Control. The Japanese beetle is not an easy insect to control. For best results the cooperative efforts of all persons living in a region of infestation are essential. In Japan where the beetle is native, it is not an important pest, probably because favorable host plants are limited there and native parasites help to hold it in check. The United States Government is introducing the more promising of these parasites to help control the beetle in this country.

Protecting the foliage.— To protect shade trees from defoliation by the adult beetles it is necessary to keep a coating of poison on the leaves just before and throughout the flying season of the beetles. The protection is obtained primarily by repelling the beetles rather than by poisoning them. For this purpose a spray composed of 6 pounds of acid lead arsenate with 4 pounds of wheat flour or 1½ pints of light pressed fish oil added to 100 gallons of water is recommended. In case it is not desirable to use lead arsenate, a spray composed of 3 pounds of aluminum sulfate and 20 pounds of hydrated lime in 100 gallons of water may be used. Where the beetles are abundant it may be necessary to repeat the spray whenever the residue from the preceding application is removed by rain or weathering action.

No satisfactory method has been found to protect those flowering plants which are attractive to the beetles, because it is not possible to keep the unfolding bloom covered with a protective residue. Also spray residue on a flowering plant destroys the beauty of the blooms. Covering such plants with a wire or cloth screen during the time the beetles are flying has been suggested.

Nonflowering plants, certain vegetables, and some fruit trees may be protected by keeping them coated with a spray composed of 1 pound of hydrated lime to 3 gallons of water. Lead arsenate is not advised for these.

Grub-proofing an established lawn.— To kill the grubs in an established lawn or other grassy area, lead arsenate without a sticker can be applied to the turf at the rate of 10 pounds to 1,000 square feet. In order to spread this small amount of lead arsenate evenly over such an area it may be mixed with dry sand or light, dry soil to give it sufficient bulk. The lead arsenate should be washed into the soil immediately after application, to remove it from the surface where it may be a hazard to man or animals and to carry it down to the roots where the grubs are feeding.

Where a power sprayer is available, lead arsenate may be applied as a spray. The lead arsenate should be mixed with the least possible amount of water to obtain a uniform distribution without flooding the turf. A mixture of 1 pound of lead arsenate to 2 gallons of water, applied at the rate of 20 gallons to 1000 square feet of lawn, has given satisfactory results when the spray material in the tank was kept properly agitated. After this spray is applied, it should be well washed into the soil to remove the poison from the grass before the spray dries. Turf may be treated with lead arsenate at any time of the year when the ground is not frozen, but best results are obtained when the poison is applied before July.

It is advisable not to apply lead arsenate to turf where cattle graze. Children should be kept from playing on recently poisoned turf until the lead arsenate has been washed into the soil so that no residue remains on the surface.

Grub-proofing a lawn under construction.— If only a few grubs are observed in the soil during the preparation of the seed bed, it is advisable to have the grass well established before the lead arsenate is applied. If the seed bed is prepared and the grass sown in the late summer or early fall, the lead arsenate should be applied the next spring when the grass has become established in order to have the poison in the soil before the grubs of the next generation appear. The directions given for treating an established lawn should be followed.

If many grubs are noticed when the seed bed is being prepared, it is advisable to apply the lead arsenate to the ground before seeding, to prevent the grubs from destroying the grass as soon as it has germinated. The lead arsenate should be applied in the dry form only, and mixed thoroughly with the top soil to a depth of 3 inches, at least 30 days before seeding, in order to kill a large proportion of the grubs before the grass germinates. Thirty-five pounds of lead arsenate to 1,000 square feet of surface may be used in such areas. Fine, dry, top soil should be thoroughly mixed with the lead arsenate to give it bulk enough to be spread evenly over the surface. Later the grass may be sown in the ordinary manner. In areas so treated the grass is slower in germinating and growing, and is darker in color than that on unpoisoned soil. Later there is little difference between the two. This treatment may be expected to make the turf immune to grub injury for about 10 years. Mowing, watering, and other operations may be practiced as usual on treated land. Although no harmful effects have been noted following the application of well-rotted manure, ammonium sulfate, sodium nitrate, potassium chloride, superphosphate, bonemeal, and lime to treated soil, inorganic fertilizers should be applied with care to avoid superficial injury to the foliage. The application of lime to poisoned turf is not recommended because it reduces the insecticidal value of the treatment. Lime should be used only when necessary to correct the acidity of the soil.

On turf where a compost of soil and manure is occasionally spread over the surface, it is necessary to avoid forming a layer of unpoisoned soil in which the grubs can survive near the surface of the ground. Therefore 2 pounds of lead arsenate should be added to each cubic yard of top dressing.

Control of grubs in flower gardens.— Grubs occasionally attacking the roots of plants in flower gardens have been destroyed by applying a carbon disulfide emulsion to the soil. This may be mixed in the proportion of 1 part by volume of resin fish oil soap, 3 parts of water, and 10 parts of carbon disulfide. Two quarts of this mixture are added to 100 gallons of water and applied to the infested soil at the rate of 3 pints to 1 square foot of surface. The application should be made in the late fall or early spring when the plants are not growing actively. An ordinary sprinkling can may be used on small areas.

Supplementary control measures.— To supplement spraying and soil-treating operations, traps are often set to reduce the number of beetles present in a locality. The traps are baited with a mixture of 10 parts of geraniol and 1 part of eugenol to attract the beetles. Another method of reducing the number of beetles is to jar them from heavily infested plants before 7.00 a. m. when the temperature is low and the beetles are sluggish. They fall readily then and may be caught in sheets spread beneath the plants and killed by being dropped into a can containing kerosene and water. It should be remembered that reducing the beetle population is only an auxiliary measure in combating this insect; main reliance should be placed on spraying the foliage and treating the soil.

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June Beetles, or White Grubs

Phyllophaga spp.

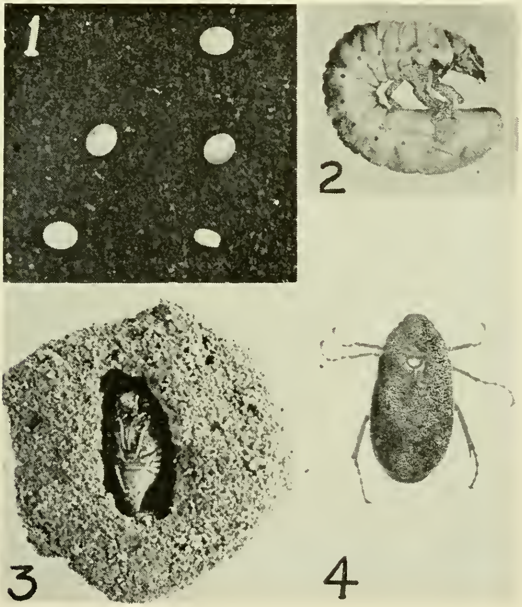
These insects, of which there are several species, cause two kinds of injury. The immature insects, known as white grubs, cause the more serious damage by feeding on the roots of lawn and pasture grasses, certain field crops, some garden plants, and nursery plantings, especially young conifers. The adults, commonly known as June or May beetles, eat the leaves of oak, ash, hickory, poplar, elm, willow, locust, hackberry, walnut, and other trees. Unlike the grubs, the beetles of different species differ, as a rule, in their preferences for host plants. The beetles feed on the foliage at night and, when abundant, may defoliate large tracts of timber. The group is widely distributed in the United States.

Description. The beetles are broadly oval with rounded bodies, measuring about ½ to 1 inch in length and varying from light to dark brown in color.

The eggs are pearly-white. When first laid they are elongate, measuring about 1/10 inch in length, but in about a week they become swollen and almost round. They are deposited in the center of balls of earth in burrows made in the ground.

The grubs are coiled into a U shape. They have thick, soft bodies with three pairs of legs. The head is brown; the body whitish, with the hind part of the abdomen darker in color. When mature, the larvae are about ¾ to 1 inch in length. The grubs of some other soil-inhabiting beetles of the same family resemble those of *Phyllophaga*, and may be distinguished only by microscopic examination.

Each pupa is enclosed in an oval earthen cell in the ground.



June Beetles or White Grubs

1. Eggs on earth. 1½×.
2. Grub. Slightly enlarged.
3. Pupa in natural earthen cell. Actual size.
4. Adult beetle. Slightly enlarged.

Figs. 1, 2, and 3. Courtesy, Bur. Ent. and Plant Quarantine, U. S. Dept. Agr.

Life History. The complete life cycle of most of the injurious species in northern United States requires three years. In northern Wisconsin two species of June beetles are reported to have four-year life cycles, while in the Southern States 2½-year cycles have been reported.

The beetles emerge from the ground in late May and June. At dusk they fly from the ground to near-by trees and feed on the foliage. A little before dawn they return to the ground. There in burrows from 1 to 8 inches below the surface the females lay their eggs within oval cavities in the center of balls of earth which are held together by a glutinous secretion supplied by the female. For egg laying the beetles evidently prefer areas in grass or small grain in the vicinity of those trees and shrubs on which they feed, although other sites may sometimes be chosen. When infested fields are planted to corn or other crops on which the grubs feed, serious injury is apt to result.

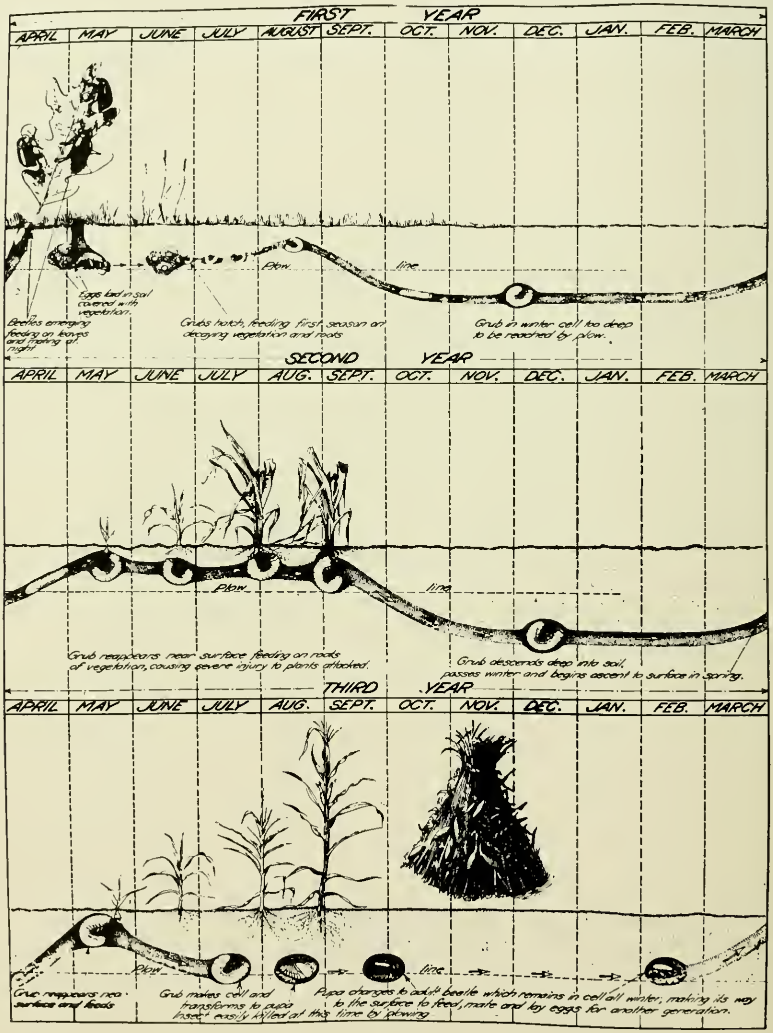

FIRST YEAR
APRIL MAY JUNE JULY AUGUST SEPT. OCT. NOV. DEC. JAN. FEB. MARCH
Plow line
Eggs laid in soil covered with vegetation.
Beetles emerging feeding on leaves and mating at night
Grubs hatch, feeding first season on decaying vegetation and roots
Grub in winter cell too deep to be reached by plow.
SECOND YEAR
APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MARCH
Plow line
Grub reappears near surface feeding on roots of vegetation, causing severe injury to plants attacked.
Grub descends deep into soil, passes winter and begins ascent to surface in spring.
THIRD YEAR
APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MARCH
Plow line
Grub reappears near surface and feeds
Grub makes cell and transforms to pupa
Insect easily killed at this time by plowing
Pupa changes to adult beetle which remains in cell all winter; making its way to the surface to feed, mate and lay eggs for another generation.

Diagram which covers a period of three years illustrating complete life cycle of white grubs and showing the periods during which they can be killed by plowing.
Courtesy, Bur. Ent. and Plant Quarantine, U. S. Dept. Agr.

The time spent in the egg stage varies from a little over a week to more than a month. The tiny grubs usually feed the first season on both decaying and living vegetable matter in the soil. With the approach of cold weather they burrow deeper into the ground and remain there through the winter. The following spring they return near the surface and feed on the roots of plants. It is at this time that the grubs do the greatest damage. In the fall they again burrow deeper into the soil to spend the second winter. The next spring they return near the surface and again feed on plant roots. Thus two years are spent by the grubs in the soil. In the early summer the individual grubs of many species prepare an earthen cell in the ground in which they transform to a pupa. (Some species may transform to a pupa the following spring.) In a few weeks the pupae transform to adults but remain in the pupal cell until the next spring when they emerge from the ground.

Although the complete life history takes three years, there is an emergence of beetles every year. The emerging beetles of each year are designated as "broods": for example, Broods A, B, and C, each brood recurring at a 3-year period. In some localities only one of these broods may be important so that an abundance would recur at 3-year intervals.

Control. Many white grubs in rough pastures and in meadows may be destroyed by plowing and disking deeply one to four times in the early fall before the grubs burrow deep into the soil for the winter. This treatment breaks up the soil, disturbs the insects, and exposes them to the elements and to predatory animals. If hogs or chickens are allowed to range on the newly plowed ground they will aid in the destruction of the grubs.

The beetles prefer to lay their eggs in grassland or in fields of small grain. Such areas, therefore, should be regarded with suspicion. If many grubs are present, the land should be plowed and disked, as mentioned above, to prevent injury to any crop which is to be planted there the following year and to prevent the beetles from emerging in numbers to attack the foliage of near-by trees.

Rotation of crops is important in avoiding white grub injury. For egg laying the beetles prefer land covered with grasses, small grains, or weeds rather than land which is in clean cultivation, in corn or a pure stand of clover; so that even in a year when the beetles are expected to be abundant the latter type of land ordinarily will contain few grubs.

The foliage of preferred host shade trees may be protected against the beetles by a thorough spray of lead arsenate at the rate of 4 pounds to 100 gallons of water with 1¼ pints of fish oil or raw linseed oil added as a sticker, if desired.

Under certain conditions the beetles may be collected or jarred from the foliage of some plants, caught in a large cloth, and then destroyed by being dropped into a can containing kerosene and water. Best results are usually obtained by collecting beetles in early morning when they are easily jarred from the trees. This should be done at the beginning of the flying season so as to destroy as many female beetles as possible before they lay many eggs.

To destroy grubs in lawns and to grub-proof lawns against this beetle, one may use the same measures advised for Japanese beetle larvae.

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Rose Chafer

Macrodactylus subspinosus Fab.

This insect is distributed from Canada and Maine south to Virginia and Tennessee and west to Oklahoma and Colorado. It is reported to be most destructive in southern New England and the Middle Atlantic States. The beetles are most abundant in and adjacent to light, sandy soil which they prefer for breeding purposes.

The beetles appear suddenly in great numbers when many early summer plants are coming into blossom. They feed on opening buds, a single beetle being capable of destroying several. They later feed on flowers and fruit, often causing serious damage. They also attack the foliage of many trees, shrubs, and vines. Roses, grapes, and peonies are usually the most severely injured, but many kinds of plants may be attacked when the beetles are abundant.

The beetles are also dangerous to chickens. There are records of one-week-old chicks having been killed by eating 15 to 20 rose chafers.

Description. The beetle is about ½ inch long and colored yellowish-brown but may become darker. It has long, reddish-brown legs which are darker at the lower end. The wing covers do not quite cover the tip of the abdomen.

The eggs are oval in shape, white and shiny in appearance, and about 1/20 inch in length.

The mature larva, or grub, resembles the white grub of the June beetle but is much smaller. The head is yellowish-brown, and the body white except the posterior portion which is darker. The legs are dark.

The pupa is light yellowish-brown and about 3/5 inch long. The last cast-skin of the grub often clings to the posterior end.

Life History. In June, about the time grapes come into blossom, the beetles appear in great numbers and attack the buds and blossoms. The foliage of various trees, shrubs, and vines is also attacked. The beetles usually feed for about 4 weeks but may be seen for about 6 weeks. Soon after emerging, the beetles mate. The females then work their way into the ground a few inches and lay eggs. Mating and egg laying occur almost continuously for a few weeks, a female depositing from 24 to 36 eggs. Light, sandy soil is generally preferred for egg laying; pastures and areas devoted to forage crops such as grass, rye, corn, and other grasses are often selected for the purpose. The eggs soon hatch and the young larvae, or grubs, feed upon the succulent roots of grass and other plants, becoming full grown by late autumn at which time they descend deep into the ground below the frost line. The next spring they work up toward the surface and transform to pupae in earthen cells. In a few weeks they become adults and dig their way out to the surface where they proceed to attack the aerial parts of plants.

Control. No satisfactory method of controlling the rose chafer has yet been found. A thorough application of 8 pounds of lead arsenate and 2 gallons of molasses to 100 gallons of water has proved fairly satisfactory when the beetles begin to appear. A second application may be necessary.

Rotenone sprays, mixed according to the manufacturers' directions and applied as soon as the beetles appear, have given promising results in some cases.

Small ornamental plants may be protected by screening during the active season of the beetles.

Hand-picking the beetles and immediately destroying them may be of some value for certain small plants.

Soil which has been infested should be plowed and disked when the insect is in the pupal stage and easily killed, which is about late May.

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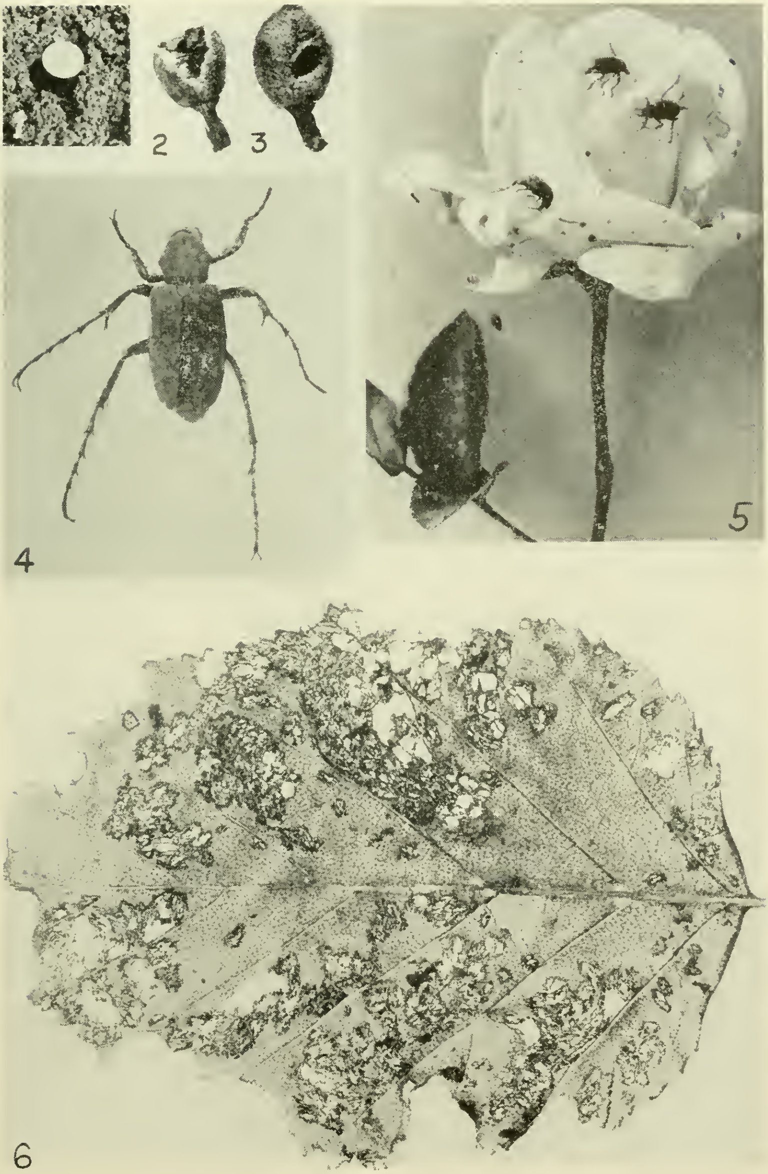


Rose Chafer

1. Egg. 2×.
2 and 3. Injured young peaches.
4. Adult beetle. Greatly enlarged.
5. Adult beetles injuring a rose. Slightly reduced.
6. Birch leaf eaten by rose chafer beetles.

Courtesy, Conn. Agr. Expt. Sta.

Dichelonyx spp.

Although this group of beetles is not considered to be important, they often appear in numbers on the foliage of various broad-leaved deciduous trees and some occur on needle-bearing evergreens, usually in the first half of the growing season.

Dichelonyx elongata Fab. is a common species with feeding habits and injury to foliage similar to those of the rose chafer, *Macrodactylus subspinosus* Fab., and has been reported on numerous species of hardwoods. Other species are *D. elongata* Schonh., on birch and alder; *D. albicollis* Burm., mostly on pine; *D. diluta* Fall., and *D. fuscula* Lec., mostly on oak; and *D. subvittata* Lec., on hazelnut and oak.

A *Dichelonyx* **Beetle.**
Enlarged.

Description. The beetles vary from about ¼ to ½ inch in length and are oblong in shape with straight sides. The general color varies from a dull brownish-yellow to a dark brown but the wing covers usually exhibit a greenish or bronze luster. The legs are mostly brown and fairly long. The mature grubs resemble those of June beetles but are smaller and differ in many characters which can be distinguished only by microscopic examination.

If control measures should be necessary, a spray consisting of 4 pounds of lead arsenate in 100 gallons of water with 2 pounds of flour or 1 pound of calcium caseinate as a sticking agent should give protection.

Blatchley, W. S. Coleoptera or Beetles (Exclusive of the Rhynchophora) known to occur in Indiana. pp. 951-953. 1910.

Britton, W. E. Conn. State Ent. Rpt. 28:680. 1929.

Britton, W. E. Conn. State Ent. Rpt. 31:505. 1932.

Doane, R. W., Van Dyke, E. C., Chamberlin, W. J., and Burke, H. E. Forest Insects. pp. 233-234. 1936.

Felt, E. P. N. Y. State Mus. Mem. 8(2):694, 703,716,723. 1906.

Gibson, A. Can. Dept. Agr. Bul. 99, N. S.: 36. 1934.

Packard, A. S. Fifth Rpt. Ent. Comm. pp. 328,511,599, 636, 801. 1890.

Imported Willow Leaf Beetle

Plagiodera versicolora Laich.

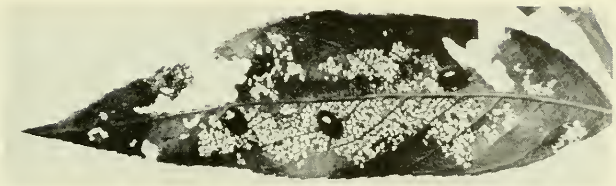
This insect is a European species. It was found in northeastern United States about 1915 and was probably introduced a few years earlier. It is becoming an important pest of willows and poplars. The grubs skeletonize the under side of the leaves and the adults riddle the foliage.

Description. The beetles are metallic blue to blue green. They are a little over 1/8 inch long and broadly oval, somewhat resembling flea beetles.

The eggs are lemon-yellow; smooth; narrowly oval in outline, with broadly rounded extremities; almost 1/25 inch long, and about 1/50 inch broad. They are laid, inclined at an angle of 30 degrees, on the under side of the leaves in masses of 12 to 30, the average being about 19.

The larvae, or grubs, are brownish-black in color, slug-like in appearance, and about ¼ inch long. Glands along their sides give off a peculiar odor.

The pupae are about 3/8 inch long and yellowish-brown in color with dark spots and markings. Usually they are attached to the under side of the leaves.



A Willow Leaf Skeletonized by Grubs of the Willow Leaf Beetle.
(Note the adult beetles on the leaf.)

Life History. The adults hibernate in crevices in the trunk and under loose bark. In the spring about early May they emerge, feed on the foliage, and begin to lay their lemon-yellow eggs in irregular masses on the under side of the leaves. These eggs hatch in a few days and the larvae, or grubs, feed on the lower surface of the leaves. In about a month they mature, attach themselves to the under side of leaves and transform to pupae, soon afterwards becoming adults. These adults eat holes through the leaves. There is probably one complete generation and a partial second in Massachusetts. Farther south, in New Jersey, there may be three generations a year.

Control. A poison spray mixed in the proportion of 3 pounds of lead arsenate to 100 gallons of water should give satisfactory control if applied when the grubs first begin to feed. The under side of the leaves especially should be sprayed. Because poplars and willows have smooth, shiny leaves it would be advisable to add 2 pounds of flour or 1 pound of calcium caseinate as a sticker.

Weiss, H. B. N. J. Agr. Exp. Sta. Circ. 100:11-12. 1918.
Weiss, H. B. N. J. Dept. Agr. Circ. 26:18-19. 1919.
Weiss, H. B., and Dickerson, E. L. Can. Ent. 49:104-109. 1917.

Willow Flea Weevil

Orchestes rufipes Lec.

This native snout weevil is widely distributed in North America. It has been reported from eastern Canada, northeastern United States south to New Jersey, the North Central States, northwestern United States south to New Mexico and north to Alaska.

The injury consists of feeding punctures caused by the adult weevils and leaf mines caused by the grubs. The adults confine most of their damage to willows but have been found feeding abundantly on other species of trees in the vicinity of willows. Early in the season the adults eat out circular holes on the tips of the new sprouts, often killing them. Most of the adult feeding, however, is done on the under side of the leaves where the beetles devour the soft leaf tissue leaving only the upper epidermis. The shallow pits are about 1/32 inch in diameter. Feeding punctures are also made on the under side of the midrib.

The mining of the leaves by the grubs evidently causes the most severe injury. The introduced laurel leaf willow, *Salix pentandra*, is injured most seriously. Blotch mines are made in the upper side of the leaves. The upper surface of these mines is slightly blistered. Trees most heavily infested by the grubs appear as if scorched by fire, and later in the summer lose many of the affected leaves.

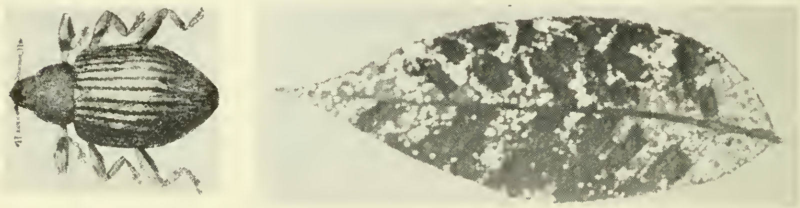
Description. The adult, which is a snout weevil, is somewhat oval in shape, about 1/12 inch long, black in color, and covered with a thin, grayish pubescence.

The legs and antennae are reddish-yellow. At the base of the wing covers is a small white spot.

The egg is white, oval to circular in shape, and about 1/60 inch long.

The mature larva is about 1/6 inch long, is widest just behind the head, and tapers slightly toward the rear. The head is dark as well as a spot just behind it dorsally which is divided along the center line. Dark, transverse spots are present along the top of the body backward from the first abdominal segment and on the under side backward from the second abdominal segment.

The pupa is about 1/10 inch long. At first it is white but later becomes almost black.



Left: **Willow Flea Weevil.** Greatly enlarged.
Right: **Willow Leaf Injured by Willow Flea Weevils.**
Courtesy, Robley Nash.

Life History. The adult weevils hibernate in the soil beneath trees, in sod, debris, under stone walls, and under loose bark or in cavities. About the time the willow buds open, the weevils go to the twigs and leaves and feed there until almost midsummer. Eggs are laid from the latter half of June until early July. They are inserted in the leaf tissue in cavities similar to feeding punctures. In about 10 days the eggs hatch and the grubs proceed to make their blotch mines in the leaves. Later they pupate in these mines and in late August the weevils of the new generation begin to appear and feed on the foliage until they go into their hibernating quarters in the fall. There is one complete generation a year.

Control. In recent tests best results were obtained with a contact spray mixed in the proportion of 1 1/3 pints of nicotine sulfate plus 1 3/5 pints of liquid potash soap to 100 gallons of water. This should be applied twice: first, during the height of the egg-laying season to kill the adults and eggs; and again, about 3 weeks later, to kill the eggs and grubs in the new mines. Both surfaces of the leaves should be sprayed. Because spraying often causes the adult weevils to drop from the foliage, the ground beneath the tree should also be thoroughly sprayed.

Nash, R. W. Jour. Econ. Ent. 27(2):336-339. 1934.
Weiss, H. B., and Lott, R. B. Psyche 28:152-155. 1921.

Cottonwood Leaf Beetle

Chrysomela scripta Fabr.

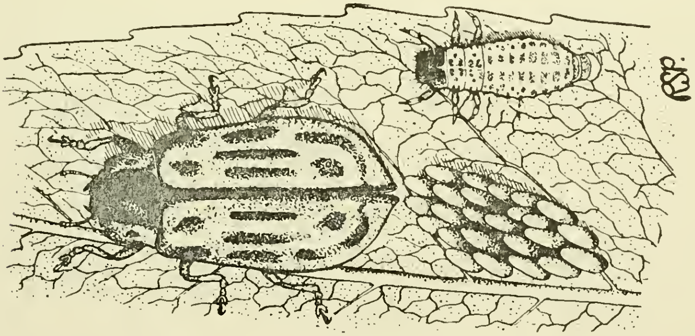
This insect is distributed over a large part of the United States. It is a serious pest of cottonwood, poplar, and willow, especially in the Western States where it has caused serious defoliation of these trees. The larvae, or grubs, skeletonize the lower surfaces of the leaves. In New York State the insects have been known to attack the succulent bark near the tips of the basket willow shoots, causing them to branch and thus become unfit for basket making.

Two closely related species also attack the foliage of poplar and willow in some parts of the country. They are *Chrysomela lapponica* Linn., and *C. tremulae* Fabr.

Description. The beetles of *C. scripta* vary in length from about ¼ to 1/3 inch. They are oblong-oval in shape. The markings on the beetles vary considerably. The head and thorax are black, the latter having broad lateral margins of brick red. The wing covers are yellow to golden, and on each are three more or less interrupted black lines which vary in size and extent so that in some beetles the gold predominates and in others the black. The side and hind margins are brick red.

The eggs are laid side by side in groups, usually on the under side of a leaf and fastened to it in a slightly slanting position. Twenty-five or more may be found in a single cluster. They are lemon yellow in color turning to a deep salmon just before hatching, elongate-oval in outline, and approximately 1/30 inch long. The shell is smooth, thick, and leathery.

The larva, or grub, is about 3/8 inch long. The body is a dirty-yellowish color, the head a dark brown, and the legs black. A double row of dark brown spots, two on each segment, extends along the upper surface of the abdomen. In line with these, on each side, is a row of black tubercles which, when the insect is disturbed, emit drops of a white, milky fluid which has a pungent odor. At the tip of the abdomen there is a disk covered with a sticky substance which is used as an aid in crawling about. When ready to pupate, the grub attaches itself to the under side of a leaf with this disk and hangs head downward. The pupae, or "hangers", are about 1/3 inch long.



Cottonwood Leaf Beetle, *Chrysomela scripta*

Adult beetle (left), egg mass (lower right), and grub (upper right). Greatly enlarged. Courtesy, N. J. Agr. Expt. Station.

Life History. The beetles spend the winter in sheltered places such as under logs or loose bark, in crevices in fence rails, or beneath debris on the ground. About the time the leaves develop, the beetles begin to feed on the leaves and tender bark of the young shoots, preferring the latter. In a few days the adults begin to lay their lemon-yellow eggs in groups, usually on the under side of the leaves. The egg-laying period lasts a week or more. Tiny, dark grubs usually appear in about 2 weeks and proceed at once to skeletonize the lower leaf surfaces.

Later they eat everything except the larger veins. They feed gregariously at first but later separate. They may also feed on the bark on the shoots. Maturity is reached in about 2 weeks, when the grubs attach themselves to a leaf by means of a sticky disk at the tip of the abdomen and pupate. They usually transform to adults in about 2 weeks. The beetles then feed on the tender leaves and bark at the tips of the willow shoots. In central New York State there are probably two broods and possibly three in some years.

Control. A poison spray of 4 pounds of lead arsenate to 100 gallons of water, applied when the larvae first appear, is recommended for the control of this insect. The under side of the leaves should be thoroughly covered. The addition of 2 pounds of flour or 1 pound of calcium caseinate should improve the adhesiveness of the spray. A second application about 2 weeks later may be necessary in a severe infestation.

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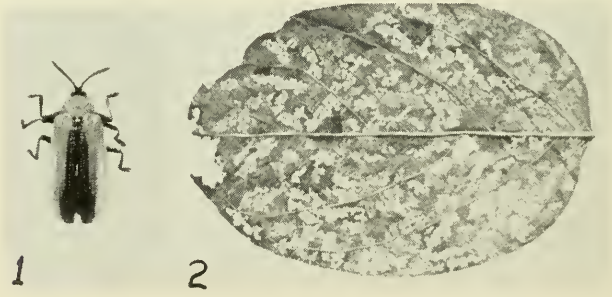
Felt, E. P. N. Y. State Mus. Mem. 8(2):564-565. 1906.
Lowe, U. H. N. Y. Agr. Exp. Sta. Bul. 143. 1898.
Packard, A. S. Fifth Rpt. U. S. Ent. Comm., pp. 428-433. 1890.

Locust Leaf Miner

Chalepus dorsalis Thunb.

This insect is known to occur in North America from Virginia north into Canada and west and south to Missouri. The foliage of black locust is attacked by the grubs and adult beetles, and serious injury has often been done to this tree. The beetles skeletonize the under surface of the leaves; and the grubs, or larvae, form large, blisterlike mines, also on the under side. The injured foliage turns brown, withers, and falls to the ground. Large areas of black locust may be defoliated. Although black locust is preferred, apple, elm, oak, beech, dogwood, wild cherry, and hawthorn as well as red clover, hog peanut, raspberry, and soybeans have occasionally been attacked, mainly by the beetles.



Locust Leaf Miner, *Chalepus dorsalis*

1. Adult beetle. Greatly enlarged.
2. Leaf injured by adult beetles. Courtesy, N. Y. State Museum, Albany, N. Y.

Description. The beetle is about ¼ inch long, flat, and orange-red in color, with head, legs, and antennae black. The inner edge of each wing cover is also black, forming a broad, black, median dorsal stripe. The wing covers are deeply punctured and each bears four longitudinal ridges.

The eggs, which are thin, flat, and oval, are deposited on the under side of the leaf and slightly overlap each other somewhat like shingles. They are covered with a brownish material which hardens soon after it is deposited. When first deposited the egg is milky-white in color.

The grub, or larva, grows to be about ¼ inch long, is somewhat flattened, and tapers slightly. When full grown it is yellowish-white, with legs, head, and thoracic and anal shield black. The segmentation of the body is plainly marked. Gubs live inside the mines which they excavate in the leaves.

Life History. The beetles pass the winter in crevices of the bark and under the litter on the forest floor. About the time the black locust leaves appear in the spring, the beetles emerge and chew small oblong holes in the leaves. In a short time the females lay their thin, flat, oval eggs on the lower surface of the leaves, rarely more than five together. When these hatch, the tiny grubs, or larvae, break through the under side of the eggs and eat their way into the leaf tissue. At first the grubs from one egg mass will occupy a single mine, but soon the larvae emerge from this mine, wander to other leaves and construct new mines. From that time on, each mine contains a single grub. The larva mines in several leaves before reaching maturity, which usually takes about 3 weeks. Transformation to the pupal stage takes place in the mine. The adults emerge about a week later and feed on the lower surface of the leaves. There is probably but one generation a year in northeastern United States. Two generations are reported to occur in Ohio and other localities.

Control. Shade and ornamental trees may be protected by spraying with lead arsenate at the rate of 4 pounds to 100 gallons of water, with 2 pounds of flour or 1 pound of calcium caseinate as a sticking agent. This spray should be applied in the spring as soon as there is sufficient foliage to retain it, in order to poison the beetles as they begin to feed.

The natural enemies of this insect often hold it in check for long periods of time so that in general serious injury by this species is confined to local outbreaks.

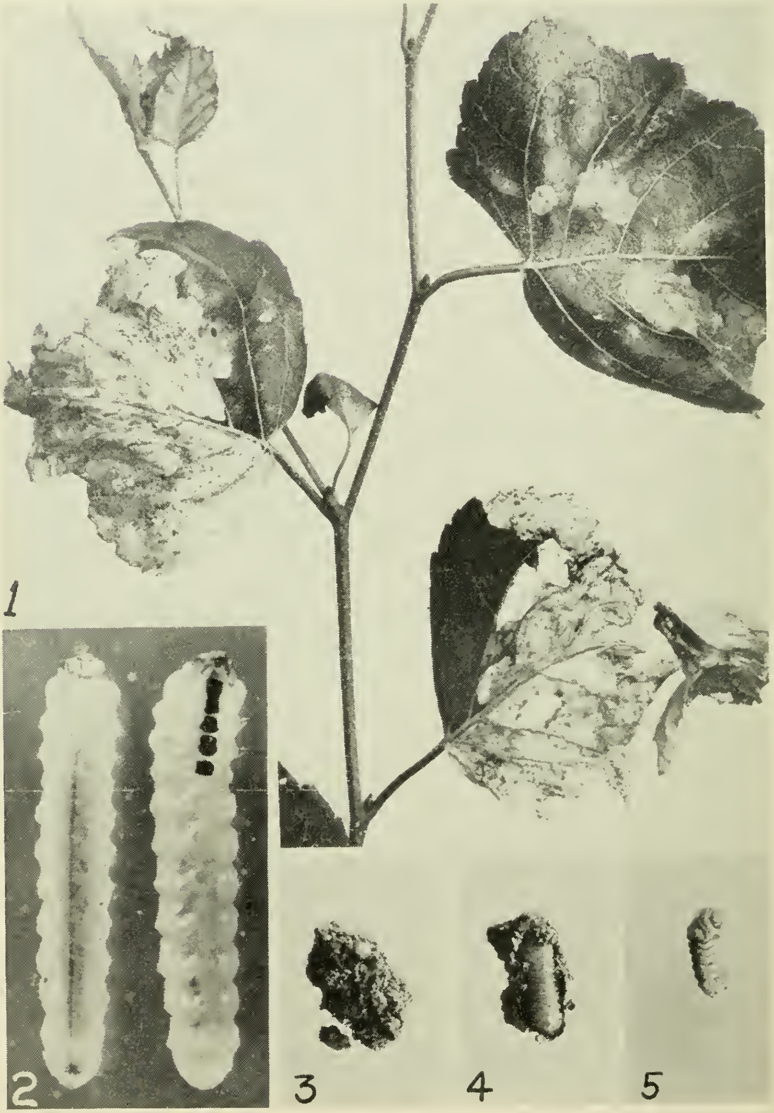
Two other closely related beetles may sometimes be found associated with the locust leaf miner, *Chalepus dorsalis.* They are *C. nervosa* Panz., and *C. rubra* Weber. The adults resemble those of *C. dorsalis* but are slightly smaller and neither has the central black stripe along the wing covers. They are seldom abundant. *C. nervosa* apparently prefers dogwood, whereas *C. rubra* apparently prefers basswood.

Felt, E. P. N. Y. State Mus. Mem. 8(2):325-329. 1906.
Houser, J. S. Ohio Agr. Exp. Sta. Bul. 322:231-236. 1918.

Birch Leaf Miner

Fenusa pumila Klug

This European species was first found in this country in Connecticut in 1923 but was probably introduced some time before. Since then it has been found in various localities in northeastern United States and southeastern Canada. Gray birch, *Betula populifolia;* white, paper, or canoe birch, *B. papyrifera;* and the European white birch, *B. alba*, are commonly attacked. Just how injurious this insect will become is difficult to determine at the present time. The tiny larvae excavate blotchy mines in the tissues of the leaves, usually starting from near the center of the blades. The affected parts become wrinkled and turn brown, and if the leaves are severely or entirely mined they fall from the tree. The terminal leaves are most frequently injured.



Birch Leaf Miner, *Fenusa pumila*

1. Birch leaves mined by larvae. (Note the young mines starting at the center of one leaf, and also the crumbled appearance of the badly mined leaves.) Actual size.
2. Larvae. 8×.
3. Cocoon. 4×.
4. Cocoon opened to show prepupa inside. 4×.
5. Prepupa. 4×.

Figs. 2, 3, 4, and 5, Courtesy, Conn. Agr. Expt. Station.

Description. The adult, a sawfly, is a small, black, fly-like insect about 1/8 inch long with a wingspread of about ¼ inch. These sawflies may be seen hovering above young birch trees or crawling over the leaves all summer.

The oval-shaped eggs are very minute, being 1/50 inch in length. Their presence in a leaf may be detected by the minute raised areas in the upper and lower leaf surfaces. When a leaf is held up to the light the eggs can be plainly seen.

The larvae are typical leaf miners. They are slightly flattened and in the young stages are translucent white in color. When fully mature they are yellowish white. Near the head are the three pairs of true legs which are small but distinct. The newly hatched larvae are less than 1/25 inch long and when full grown almost ¼ inch long.

The cocoons in which the larvae pupate in the ground are small earthen cells. The pupae inside are white, almost 1/6 inch long, and show the presence of all the adult appendages.

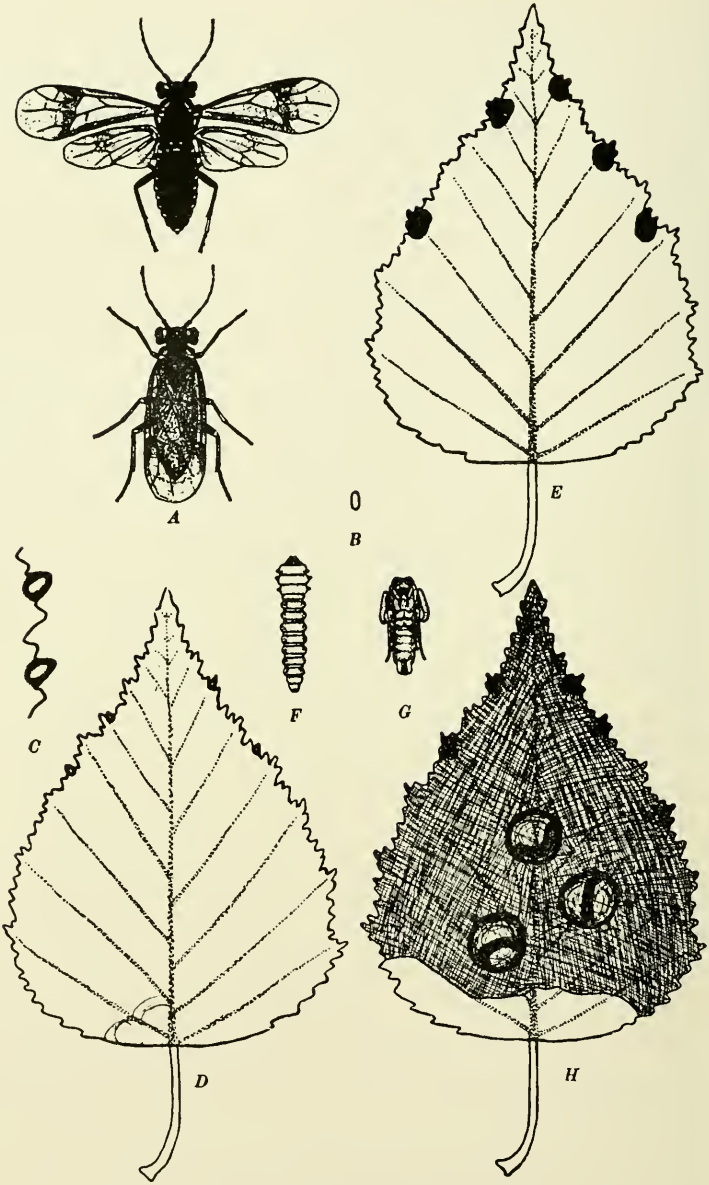
Life History. The first tiny sawflies begin to appear about the middle of May, and lay their eggs in the young developing birch leaves, often when the leaves are ½ to ¾ inch long and before they completely unfold. Eggs are not deposited in the older mature leaves in which the tissues have hardened. Because of this selection only the newly developing leaves at the tips of the branches are selected for egg laying as the season advances. The eggs are laid separately throughout the central area of the leaf. They soon hatch and each young larva begins to excavate a mine in the leaf tissues. The mines are separate when small; but, as the larvae increase, the mines coalesce and form a large, hollowed-out, brown area in the leaf. Although the period of development varies widely, usually the larvae mature in about 10 to 15 days. They then emerge from the leaf, drop to the ground, burrow beneath the surface and form a cocoon of particles of soil, transform to pupae, and emerge as adults about 2 or 3 weeks later. There are perhaps 3 generations a year, but due to the variation in the time of development the various generations overlap, especially toward the end of the season. Fast-growing birch sprouts which put out an abundance of new foliage all season, may be expected to be attacked constantly during the growing season. On well-grown trees, however, on which the foliage hardens in midsummer, the infestation will decrease sharply after that time. From early August on, an increasing proportion of the larvae which enter the soil remain there over winter as prepupae and transform to pupae and adults the next spring.

Control. Recent experiments indicate that the eggs can be killed by a contact spray of 40 percent nicotine sulfate at the rate of 1 pint to 100 gallons of water. For the first generation of eggs, 2 applications spaced about a week apart should be applied. The first should be put on in late May. For eggs of the second generation, 3 applications spaced about a week apart are necessary, the first to be applied about the first week in July. Both surfaces of the leaves should be well sprayed.

Friend, R. B. Jour. Econ. Ent. 24(1):171-177. 1931.
Friend, R. B. Conn. Agr. Exp. Sta. Bul. 348. 1933.

Birch Leaf-Mining Sawfly
Phyllotoma nemorata Fallen

About 1905 this insect was first found in America in Nova Scotia. At first it was thought to be a newly discovered native species but later it was found to be of European origin. It aroused little concern until 1927 when a very heavy



Birch Leaf-Mining Sawfly, *Phyllotoma nemorata*

A. Adult sawflies. Lower one in normal resting position. 4×.
B. Egg. 4×.
C. Eggs in leaf teeth. 4×.
D. Eggs in leaf. Actual size.
E. Mines in leaf, showing best time to spray. Actual size.
F. Last stage larva. 2×.
G. Pupa. 2×.
H. Hibernacula in mined leaf. Actual size.
Courtesy, Maine Forest Service.

infestation occurred over wide areas in Maine, causing the birch foliage to turn brown as if scorched by fire. The insect has since spread into New Hampshire, across into northeastern New York, and also into parts of Massachusetts. Although all species of birch except black birch, *Betula lenta*, have been reported attacked; white birch, *B. papyrifera*, and gray birch, *B. populifolia*, are evidently preferred. The leaves of alder and hazelnut have also been reported mined. The larvae excavate blotchy mines in the tissues of the leaves. The affected areas turn brown but, unlike those mined by the birch leaf miner, *Fenusa pumila*, which become wrinkled and contain frass, these leaves usually retain their normal form and are fairly free from excrement. Severe infestation greatly reduces the rate of growth in the season following the attack since it occurs when the trees are storing up food for the succeeding year.

Description. The adult female is from 1/8 to 3/16 inch long and 1/25 to 2/25 inch wide. The general body color is jet black. The wings are hyaline and somewhat iridescent and the fore part of each front wing bears a dark spot. No males have been reported found.

When first deposited, the egg is about 1/50 inch long, half as wide, and oval in shape. It is grayish-white in color.

The full-grown larva is about ¼ inch long. The head is dark; the three body segments behind the head, broad and flat; and the rest of the body segments taper toward the rear.

The pupa is creamy-white to yellow, changing to dark gray and black. All the adult appendages are present and closely appressed to the body.

Life History. Near Bar Harbor, Maine, the female sawflies begin to appear about June 20, and may be found through part of July. In Massachusetts they may appear a few weeks earlier, while in the higher and more northern parts of Maine they may appear a few weeks later. The greatest emergence occurs on warm, calm, sunny days. Soon after emerging, the female inserts her eggs through a slit in the upper surface of the leaf into the inner tissues on the margin of the leaf, usually on the two-thirds of the leaf margin nearest the tip. As a rule the full-grown, well-formed leaves on the current year's stem growth are chosen for egg laying. In a short time the leaf tissues surrounding the egg begin to darken and the location of the egg can easily be seen. The egg apparently swells soon after being laid and its presence can be detected by the appearance of a bulge on the surface of the leaf. Twelve eggs may be laid in a single leaf. The eggs hatch in about 20 days. As the larvae begin to feed, the mined areas appear as small brown patches on the edges of the leaf. They are hardly noticeable at first but in about a week show very plainly. As the individual mines enlarge they may merge with one another. In feeding, the larvae shear through the veins. Most of the mining is done in the outer two-thirds of the leaf blade. Feeding continues into the fall. At that time, unlike the larvae of the other introduced birch leaf miner, *Fenusa pumila*, which when full grown desert the leaf, hibernate, and then undergo their transformation in a small earthen cell in the ground, the full-grown larvae of *Phyllotoma nemorata* form inside the leaf mine flat, usually circular cells in which they pass the winter in the fallen leaves. Although larvae are said to kill each other when their mines meet, it is not unusual to find 2 to 5 of these cells in a single leaf. Each cell is about ¼ inch in diameter, quite tough, and coated inside with a varnish-like, waterproof substance that protects the larva during the winter. If an infested leaf is held up to the light, the enclosed larva in its cell may be easily seen. In the latter part of June the larvae transform to pupae inside these cells in the leaf and soon become adults, emerge, and fly away. Larvae are said to develop somewhat more rapidly in gray birch than in white. In Maine and northeastern New York there is only one generation a year. As the insect spreads farther south, however, there is the possibility that two or more generations may be produced in those regions.

Control. For ornamental trees a spray of 40 percent nicotine sulfate, 1 pint to 100 gallons of water plus 4 pounds of laundry soap, is recommended to control this insect. Spraying should be done on warm days but not on hot, sultry days when water scald might result. This spray should be applied to the foliage after practically all the eggs have been deposited but before many of the largest leaf mines reach a diameter of ¼ to 3/8 inch. Later the larvae are more resistant to the spray and are not so easily killed.

Bordeaux mixture is reported to be an effective repellent if applied just as the adults begin to appear. A second application should be made 2 weeks later.

Brower, A. E. Jour. Econ. Ent. 26(3):732. 1933.
Brower, A. E. Jour. Econ. Ent. 27(2):342-344. 1934.
Craighead, F. C., and Middleton, W. U. S. Dept. Agr. Misc. Pub. 74:23. 1930.
Friend, R. B. Conn. Agr. Exp. Sta. Bul. 348:330. 1933.
Glasgow, R. D. Jour. Econ. Ent. 25(3):693-695. 1932.
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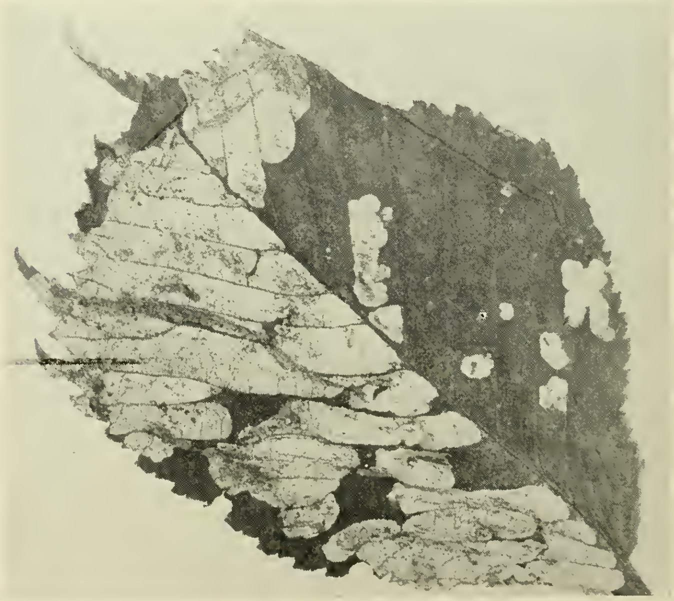
Peirson, H. B., Taylor, R. L., and Wilkins, A. H. Maine Forest Service Circ. 1. 1930.

Elm Leaf Miner

Kaliosysphinga ulmi Lund.

The elm leaf miner is native to Europe. It is supposed to have entered this country prior to 1898, and now is commonly found throughout northeastern United States.



Leaf of Camperdown Elm Mined by Larvae of the Elm Leaf Miner.

The tiny grubs of this insect mine in the tissues between the upper and lower epidermis of the leaves, especially of Camperdown, English, and Scotch elms. The mines appear first as tiny whitish spots but soon become large, blotchy, whitish areas, bounded by the lateral leaf veins. Several grubs may attack a single leaf, and their individual mines coalesce, hollowing out the whole leaf. In this case the leaf will soon wither and fall. If only a small portion of the leaf is mined the epidermis will dry and crack, leaving holes in the leaf. This injury spoils the appearance of ornamental trees, and when the infestation is severe seriously weakens them.

Description. The adult is a tiny, shiny black sawfly. It is about 1/8 inch long and has a wingspread of about ¼ inch.

The mature grub is about 1/3 inch long, flat, and whitish in color with a pale brown head. The legs are encircled with brown.

The cocoons are very small, tough, brown, and cylindrical.

Life History. The mature grubs hibernate in cocoons under the surface of the soil. They pupate in the spring, and about the middle of May emerge as four-winged flies. The females usually lay their eggs in the upper surface of the leaves. During the latter half of May the young grubs begin to mine the leaves. By early July they finish feeding, desert the mines, and go to the ground to construct their cocoons. There is one generation a year.

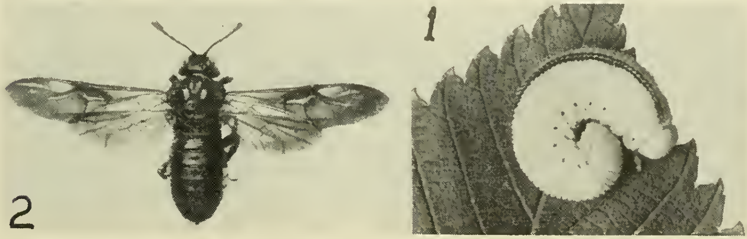
Control. This insect may be controlled by thoroughly spraying the foliage in the spring, as soon as the tiny, blister-like mines appear, with 1 pint of 40 percent nicotine sulfate to 100 gallons of water with 5 pounds of soap as a spreader.

Felt, E. P. N. Y. State. Mus. Mem. 8(1):162-163. 1905.
Herrick, G. W. Cornell Univ. Agr Exp. Sta. Bul. 333:508-511. 1913.
Slingerland, M. V. Cornell Univ. Agr. Exp. Sta. Bul. 233:49-57. 1905.

Elm Sawfly

Cimbex americana Leach

This large native insect is widely distributed in northern United States and southern Canada. It attacks elm and willow chiefly but is also found on poplar, maple, linden, and alder. In Massachusetts it is not considered to be important although, because of its large size and the conspicuous color of the larvae, it occasionally attracts attention. The larvae feed on the foliage and cause most of the damage. The adult sawflies have been reported occasionally to girdle the stems of willow.



Elm Sawfly

1. Larva on leaf Courtesy, Robert L. Coffin.
2. Adult sawfly.

Description. The adult is a sawfly from ¾ inch to 1 inch long. The fore part of the body is shining black in color. The abdomen is steel-blue and has on each side three or four oval, yellowish spots which vary in size in different individuals. The wings are semitransparent, smoky-brown in color, and measure about 2 inches when spread. The body of the male is somewhat thinner and longer than that of the female.

The mature larva is between ¾ inch and 1 inch long. It is pale yellow with a black stripe along the middle of the back. The body bears numerous small, flattened, wart-like growths. Along the side near the lower edge is a series of small, black spots. When at rest the larva characteristically assumes a curled position like other sawfly larvae.

The cocoon in which the larva pupates is tough and coarse, broadly oval in outline, dark brown in color, and about ¾ inch to 1 inch long.

Life History. In the spring, about May, the adult sawflies appear. The females insert the eggs singly into the tissues of the leaf. The places where the eggs are laid appear as tiny, blister-like swellings and are most easily seen from the under side of the leaf. From 1 to 12 eggs or more may be placed in a single leaf, and one female may lay about 500 eggs. After several days the eggs hatch and the individual larvae finally emerge from their tiny cell through an irregular slit in the leaf. The newly hatched larvae are uniformly curled up on the under side of the leaves. They feed on the foliage and become full grown in late July or in August. They then go to the ground near the base of the tree on which they developed and spin a tough, coarse, silken cocoon among the debris or just below the surface of the ground. The insect passes the winter in the larval stage, pupates in the spring, and emerges as the adult about May. There is thus one generation a year.

Control. Usually not enough damage is done in this region to warrant the use of control measures. If treatment should be necessary, a spray consisting of 4 pounds of lead arsenate to 100 gallons of water, with the addition of 2 pounds of flour or 1 pound of calcium caseinate as a sticking agent, is effective. This should be applied when the larvae are young and small. In some sections of the West where the insect is considered an important pest of willows, raking and burning the cocoons in the late fall and early spring have proved satisfactory as supplementary control measures where only a few trees are concerned.

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Maple Petiole Borer

Caulacampus acericaulis MacG.

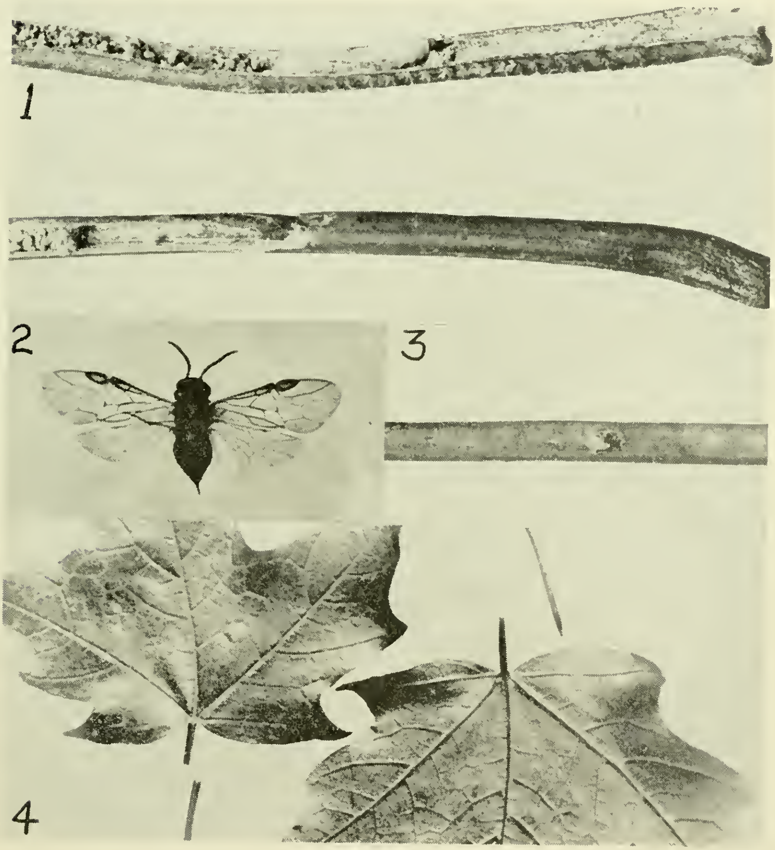
In 1909 this insect was first discovered in Connecticut. It has since been found in Massachusetts.

The tiny larvae tunnel in the petioles, or leaf stems, of sugar maple, causing them to break off ¼ to ½ inch from the blade of the leaf. The blades fall from the tree in late May and early June. The leaf stems fall one or two weeks later. The lower parts of the tree are usually affected. In a serious infestation a tree may lose as much as one-third of its foliage.

Description. The adult is a small, four-winged fly known as a sawfly. The wings are transparent. The fore part of the body is black; the abdomen and legs, honey yellow.

The egg is colorless, 1/25 inch long and 1/5 as thick, curved, and with blunt, rounded ends.

The mature larva is about 1/3 inch long and 1/16 inch thick. It is light yellow with a dark yellow or light brown head.



Maple Petiole Borer

1. Larva in petiole or leaf stem. Enlarged.
2. Adult female. Enlarged.
3. Exit hole of larva in leaf stem. Enlarged.
4. Leaves with severed stems.

Courtesy, Conn. Agr. Expt. Station.

Life History. The egg is laid on the leaf stem at the base of the blade, in early May. The young larva tunnels in the leaf stem and feeds on the inner tissues, leaving only an outer shell filled with frass and excrement. The outer sheath is usually eaten almost through by the time the larva matures, which is about 3 weeks later, and the stem breaks at that point. Most of the leaf stem remains on the tree a week to 10 days and then drops off. The larva contained therein emerges through a small hole in the side and goes into the ground 3 or more inches where it pupates in an earthen cell in which it spends the winter. The adult emerges the following May.

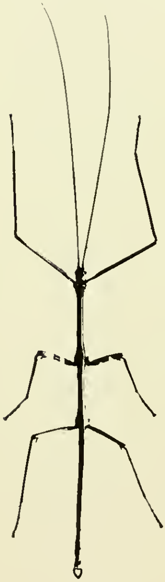
Control. Some degree of control may be obtained by picking up the fallen leaf stems every day and immediately burning them before the larvae leave them and enter the ground.

Britton, W. E. Conn. State Ent. Rpt. 11:305-307. 1911.

Walkingstick

Diapheromera femorata Say

This interesting insect is so named because of its remarkable resemblance to a stick or twig. Because of this resemblance it usually escapes notice when feeding on foliage. It is considered to be of little importance but occasionally becomes locally abundant and may defoliate large forested areas in the late summer and early autumn. It attacks the foliage of most deciduous hardwoods, but seems to prefer oak, maple, basswood, and locust. Pitch pine has also been reported to be attacked.



A Walkingstick

Courtesy, Mich. Agr. Expt. Station.

Description. The body of the mature insect is about 3 inches long and is extremely slender, resembling a stick or twig. From the front of the small head two long antennae extend forward. The legs are also slender and about 1½ to 2 inches long. The females are stouter than the males. Both are wingless. The color varies, but shades of gray, brown, and greenish-brown predominate.

The eggs are hard, bean-shaped, highly polished, slightly less than 1/16 inch long, and black in color with lighter mottled markings.

The young, or nymphs, resemble the adults in form. When newly hatched they are about 3/8 inch long and are colored a pale yellowish-green. The front legs are speckled with brown.

Life History. In the autumn, as the adults feed on the foliage, the eggs are dropped at random, falling among the leaves and litter beneath the trees. The following spring, usually in May, these eggs begin to hatch although some may not hatch until the second spring. The nymphs become full grown in late summer and early autumn. There is only one generation a year.

Control. Walkingsticks are seldom abundant enough in Massachusetts to require any special control measures. If necessary, shade and ornamental trees can be protected against this insect by an application of lead arsenate at the rate of 4 pounds to 100 gallons of water, with 2 pounds of flour or 1 pound of calcium caseinate to increase adhesiveness.

The application of lead arsenate as a dust is also reported to have been successful. Lead arsenate may be used in a 90:10 or 85:15 mixture with hydrated lime.

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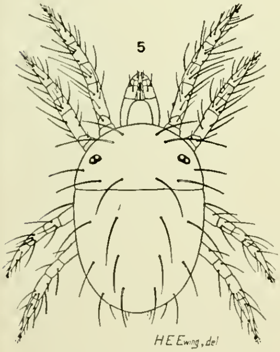
Packard, A. S. Fifth Rpt. U. S. Ent. Comm., pp. 317-321. 1890.
Peirson, H. B. Maine Forest Service Bul. 5:33-34. 1927.
McDaniel, E. I. Mich. Agr. Exp. Sta. Spec. Bul. 243:5-6. 1933.

Red Spiders, or Mites

Red spiders, or mites, are not true insects but belong to the same group as spiders. They do not chew foliage as do many species of insects but suck the plant juices with their sharp-pointed, piercing mouth parts and sometimes cause very serious injury to the foliage of plants.

There are numerous species of mites which attack many kinds of broad-leaved trees and cause various types of injury, such as the growth of leaf galls, the appearance of velvety patches on the leaves, and the discoloration of the foliage. This discoloration is the result of the removal of the green coloring matter of the leaf in the vicinity of the puncture made by the insertion of the piercing mouth parts into the tissues of the leaves. Severely affected foliage becomes mottled in appearance and later brownish or rusty as though scorched. Badly infested leaves may fall prematurely, thereby reducing the vitality of the tree. Many needle-bearing evergreens are also injured by mites.

Mite attack may be identified by the following: numerous tiny discolored spots on the leaves; very fine strands of silk stretched over the leaf surfaces, which at times may become very noticeable; and tiny spherical eggs and broken egg shells. Mites are very minute in size, and vary in color. The body is oval with long spine-like hairs. There are four pairs of legs.



Common Red Spider,
Tetranychus telarius.
Greatly enlarged.
Courtesy, Oreg. Agr. Expt. Station.

The common red spider, *Tetranychus telarius* L., attacks many broad-leaved trees and shrubs. In the Northern States it is reported to pass the winter successfully as an adult or a second stage nymph beneath debris and in loose, dry soil.

The European red mite, *Paratetranychus pilosus* Can. and Fanz., is common on apple and other fruit trees. It is reported to attack elm and a few other shade trees occasionally. It passes the winter in the egg stage upon the smaller twigs and branches. The eggs of this species are dark red, and masses of them appear like red brick dust on the twigs.

The spruce mite, *Paratetranychus ununguis* Jacoby, is common on some of the needle-bearing evergreens such as spruce, arborvitae, and red cedar. It spends the winter in the egg stage around the bud scales and at the base of the needles. The eggs are brown.

When warm weather approaches, these and other mites attack the leaves, producing the characteristic injury described above. Mite injury is usually most abundant during hot, dry weather. Several generations are produced a year.

Control. Where sufficient water pressure is available and the size of the trees permits, drenching infested trees and shrubs frequently with a hose helps to reduce mite infestation by washing off the mites.

During the spring and summer after the new foliage appears, an application of one of the wettable sulfurs at the strength recommended by the manufacturer should give satisfactory control of mites if it is applied when the temperature is high.

For those mites which overwinter in the egg stage on fruit trees or evergreens, in addition to the above summer spray a dormant spray of a miscible oil or oil emulsion, diluted according to the directions of the manufacturer and applied in the spring before the buds begin to swell, will give satisfactory control. It must be remembered, however, that oil sprays, if not properly applied, are apt to burn the twigs and bark, and in the case of evergreens the needles also. The bloom is usually removed from the needles of evergreens but unless the needles are actually burned the natural color eventually returns. To reduce the chances of spray burn, follow the manufacturer's directions carefully. Do not apply when the temperature is below 40° F. or when a freezing temperature may occur before the spray dries. Apply only enough spray to give a thorough coverage, and as an added precaution do not apply more than once in three years to needle-bearing evergreens.

Bourne, A. I., and Whitcomb, W. D. Mass. Agr. Exp. Sta. Bul. 339:46-47. 1937.
Britton, W. E., and Friend, R. B. Conn Agr. Exp. Sta. Bul. 369:296. 1935.
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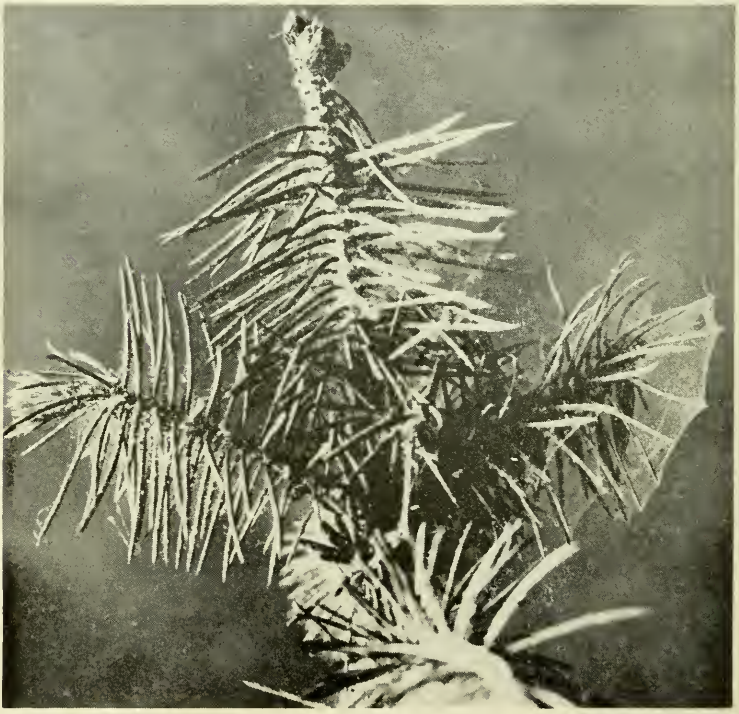

Web Formed by Mites on Spruce Twigs.

Courtesy, Conn. Agr. Expt. Station.

TREE INJURY BY SQUIRRELS

By E. M. Mills, Assistant Biologist, U. S. Biological Survey, Amherst, Mass.

The damage to shade trees inflicted by squirrels closely resembles insect damage, particularly in the case of twig injury after it has healed. A knowledge of the habits of both squirrels and insects is essential for differentiating between the types of shade tree injury. In a general way damage by squirrels can be distinguished from insect injury by the time of year at which it occurs. Most squirrel damage is done during winter and spring, while insect injury occurs during the warmer months of summer. Injury to shade trees by squirrels should not be confused with that caused by deer or certain birds, such as the pine grosbeak.

Injury to Seeds, Nuts, Fruit, and Buds. The staple food of the red and gray squirrels consists of seeds, buds, and nuts of many deciduous trees and seeds of conifers. In fall and winter, hickory nuts, chestnuts, beechnuts, acorns, and other nuts are the important items of food and are often stored for use during periods of severe weather. Squirrels also consume the seeds from the cones of such trees as pine, spruce, fir, and hemlock. These cones are often buried in the ground during the fall to be recovered later in the year. Squirrels will attack such fleshy fruits as the berries of the flowering dogwood, apples, pears, and other fruits of shade and ornamental trees, mainly for their seeds. In spring, the buds of maple, elm, beech, ironwood, birch, willow, poplar, and spruce are consumed eagerly and in large quantities.

Elm Twigs, in Seed, Removed by Gray Squirrels.
Courtesy, Conn. Agr. Expt. Station.

Injury to Twigs. Probably the most serious type of injury to shade trees by squirrels is the cutting of twigs. When ground food is not available because of heavy snow, the squirrels resort to feeding upon twigs. In coniferous plantings they cut off sharply the leader or terminal shoots, chiefly to feed upon the cluster of buds and sometimes the ends of the top branches. This causes the trees, especially Scotch pine and Norway spruce, to become stunted or deformed.

An interesting account of injury to elm twigs is given by Professor Deuber of Yale University. He observed two gray squirrels making their entire diet on elm seeds during the latter part of May and early in June. They cut off twigs with fresh leaves in order to reach the seeds more easily, the twigs falling to the ground. In one day he found 892 twigs on the ground. In another case, two pairs of squirrels in a little more than one day cut 2,886 twigs with 14,430 leaves. The tree had been sprayed with arsenate of lead, but the squirrels were not deterred.

Injury to Bark. Squirrels occasionally gnaw the bark, or girdle trees. The sugar maple seems to be the most attractive to them as they relish the sap. Both large and small branches may be chewed. Similar injury to coniferous trees has also been reported. Damage to the bark may be in scattered patches throughout the woodlands, or the squirrels may continue on the same tree or limb for a long period and the tree may eventually die as a result.

Total Injury Not Serious. In general, squirrels are not a serious problem in the propagation of shade trees. The relatively few nuts and seeds taken are negligible, and the buds eaten do not materially retard the growth of most trees. Squirrels may become a pest, however, by consuming large quantities of seeds, buds, and fruits of choice ornamental shade trees, and they may become a nuisance by littering the lawn with twig clippings. Serious damage to twigs or bark is most likely to occur during extremely severe winters, when valuable trees may be badly injured.

Control. Few persons wish to kill these interesting animals. No general campaign should be waged against them, for damage is probably local and done by only a few squirrels. In severe winters, it might be well to feed them. A mixture of corn, hard-shelled nuts, and sunflower seeds is recommended.

If it becomes necessary to control squirrels, they can easily be trapped in a box or wire cage trap and transferred to other localities. They can also be trapped in a No. "0" or No. "1" steel trap baited with nutmeats. The traps should be set at the base of trees where the squirrels have been observed to feed, or at other places along their route of travel. Local trapping regulations must be considered. Shooting is also a practical method if State and local ordinances permit. Gray squirrels are protected by law in Massachusetts except during a month's open season.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

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Ascorbic Acid (Vitamin C) in Tomatoes and Tomato Products

By Walter A. Maclinn and Carl R. Fellers

The tomato is one of the richest and most widely used sources of vitamin C. Yet much remains to be learned of the influence of inherited and external factors on its vitamin content. This study was undertaken in the hope of filling in some of these gaps in our knowledge.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

Ascorbic Acid (Vitamin C) in Tomatoes and Tomato Products

By Walter A. Maclinn, Instructor in Horticultural Manufactures, and Carl R. Fellers, Research Professor of Horticultural Manufactures

INTRODUCTION

The tomato ranks among the richest and most widely used of antiscorbutic foods, but in spite of its popularity, comprehensive studies of the factors influencing the ascorbic acid content in the tomato are lacking. True, considerable attention has been directed to the evaluation of the various manufactured tomato products, in terms of ascorbic acid; but the effect of season, variety, maturity, storage, and many other factors have been only incompletely studied.

Previous to 1932 when Tillmans, Hirsch, and Hirsch discovered a chemical titration method of determining ascorbic acid, the only method available was the 90-day, guinea-pig bioassay. Naturally, progress was slow under these conditions, and in many cases, conflicting results were reported. Furthermore, the animal method is not sufficiently accurate to determine small differences in ascorbic acid content. Another recent discovery (Tillmans, Hirsch, and Dick, 1932) was that the ascorbic acid in fresh fruits and vegetables often is present in the reversibly oxidized form of dehydroascorbic acid. There is still some question as to whether this substance possesses the full value of ascorbic acid in the prevention and cure of scurvy.

The first step in this investigation naturally seemed to be a comparison of the newly devised chemical titration method with the standard animal bioassay. This had not been done previously for tomato products. Since sampling methods, reagents, and technic were not well standardized, it was necessary to make a careful quantitative study of these several factors before the rapid chemical methods could be adapted with a degree of assurance to the evaluation of ascorbic acid in tomatoes and tomato products.

REVIEW OF LITERATURE

There is difficulty in covering the entire literature on tomato and tomato products as a source of ascorbic acid, because in some cases the tomato analysis may be secondary in importance to some other phase of ascorbic acid investigation, and therefore no mention is made of the tomato in the title or summary. There are a number of reviews or summaries of ascorbic acid investigations that refer to the tomato: Kohman in 1929, Sherman and Smith in 1931, Report of the British Medical Research Council in 1932, Fellers in 1936, Daniel and Munsell in 1937, and less complete surveys by Bacharach (1933), Smith (1929), Scheunert (1930), Priestly (1933), Dutcher (1932), Fellers (1935), and Cowell (1936).

Besides the discussion of salient papers on the ascorbic acid content of tomatoes and tomato products, this review includes a summary in tabular form of all reported references however brief (Table 1).

The terminology used in the reports varied widely, including Sherman units, milligrams of ascorbic acid, and even qualitative words such as good, fair, or poor. For uniformity in this summary table the ascorbic acid content is expressed in milligrams per gram and international units. An international unit represents the antiscorbutic activity of 0.05 mg. l-ascorbic acid. Factors for converting some of the reported results into international units could not be accurately determined; but when it became necessary to interpret data, every effort was made to do this consistently and logically.

The description and identification of the tomato or tomato product in Table 1 is that given in the report from which the data were taken. In a large majority of cases, however, little information other than the product used was given and in the processed tomato lack of standardized procedures makes interpretation difficult.

Unless otherwise stated, the methods employed in the work reviewed here are the biological assay method of Sherman, La Mer, and Campbell (1922) or the chemical titration method using 2, 6-dichlorophenolindophenol.

Raw Tomatoes

The influence of chromosome number on the ascorbic acid content of the tomato has been the subject of considerable discussion in the literature. Key (1933) found that tomatoes of the same genetic constitution, whether of diploid (12 pair) or tetraploid (24 pair) chromosome number, contained equal quantities of ascorbic acid. Sansome and Zilva (1933, 1936) found that tomatoes with tetraploid number of chromosomes have approximately 40 percent more ascorbic acid than those of the diploid chromosome number. McHenry and Graham (1935) stated that chromosome number does not influence the ascorbic acid content of tomatoes. They claimed that the differences found by other authors were due to fruit size, as the tetraploid tomatoes are usually smaller than the diploid tomatoes. Consequently, the ascorbic acid is more concentrated per unit of weight in the smaller tomatoes of the same genus. Lindstrom,[1] in a personal communication, stated that all cultivated varieties of tomatoes are of the diploid type, having 12 pairs of chromosomes. He also noted that, although it is not difficult to obtain a tetraploid of any variety, they are not practical as the fruit or seed set is poor.

Tripp, Satterfield, and Holmes (1937) studied the ascorbic acid content of 10 varieties generally produced in North Carolina. The varieties in which the ascorbic acid content was highest were Pritchard (0.218 mg. per gram) and the Louisiana Pink (0.217 mg. per gram). In descending order of ascorbic acid content the other varieties tested were: Greater Baltimore, Break-o'-Day, Scarlet Dawn, Grothen, Louisiana Gulf State, Walter Richards, and Marglobe. The John Baer variety showed the smallest amount of ascorbic acid (0.148 mg. per gram). These investigators found no constant relation between the size of the tomato and its ascorbic acid value.

Krauss, Washburn, and Hoffman (1937), and Hoffman[2] tested 71 varieties and strains for ascorbic acid but gave no data in their preliminary reports. They stated that rather wide differences were found among the varieties regardless of color; this confirmed their observations of the previous year, that color, per se, is not associated with ascorbic acid. Stage of maturity and acidity were found to be closely correlated with ascorbic acid potency. Acidity increased rapidly as the fruits reached full size, but decreased somewhat during the ripening process. Ascorbic acid increased with acidity within the variety. During the ripening of the fruit there was a small reduction in the quantity of ascorbic acid, accompanying a small loss in acidity, but during the final softening of the ripe fruits the ascorbic acid content again increased rapidly. These investigators also found that different soil types produced little or no change in ascorbic acid content if well

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[1] Lindstrom, E. W., 1936. Personal communication.

[2] Hoffman, I. C., 1937. Personal communication.

TABLE 1.—ASCORBIC ACID CONTENT OF TOMATOES AND TOMATO PRODUCTS—PUBLISHED REPORTS

Description of Samples	Assay Method	Ascorbic Acid		Investigator
		Mg. per Gram	I. U. per Ounce	
Raw Tomatoes:				
Chinese	guinea pig	especially rich	. . .	Sah, Ma, and Chang (1934)
English	Sherman	.25	142	Delf (1925)
German	guinea pig	good source	. . .	Rojahn and Wirth (1932)
Hawaiian	dye	.20	113	Miller (1930)
Indian	guinea pig	.10	57	Wats and Eyles (1931)
Mexican	guinea pig	.05	28	Vinokurov (1934)
Mexican	guinea pig	.05	28	Zorin (1934)
Spanish	guinea pig	.33	187	Cadenas and Olmedo (1934)
71 varieties	dye	wide variation	. . .	Krauss, Washburn, and Hoffman (1937)
71 varieties	dye	.11–.46	62–260	Krauss, Washburn, and Hoffman (1938)
Ten varieties	dye	.15–.22	85–125	Tripp, Satterfield, and Holmes (1937)
Eight varieties	dye	.16–.31	91–175	Tressler (cited from Daniel and Munsell, 1937)
Bonny Best	Sherman	.14	79	Spohn (1931)
Globe	Sherman	.14	79	Ditto
Diploid	dye	.28–.38	158–215	Sansome and Zilva (1936)
Tetraploid	dye	.41–.48	230–272	Ditto
Diploid	dye	.36	204	McHenry and Graham (1935)
Tetraploid	dye	.43	243	Ditto
Juice (diploid)	Sherman	.11	62	Key (1933)
Juice (tetraploid)	Sherman	.11	62	Ditto
Green	Sherman	.10	57	House, Nelson, and Haber (1929)
Green	Sherman	.07	40	Kohman, Eddy, and Zall (1930)
Unripe	dye	.27	153	Giroud, Ratsimamanga, and Leblond (1935)
Picked green and allowed to ripen	dye	as potent as vine ripened	. . .	Clow and Marlatt (1930)
Air ripened	Sherman	.12	68	House, Nelson, and Haber (1929)
Ethylene ripened	Sherman	.12	68	Ditto
Vine ripened	Sherman	.12	68	Ditto
Winter ripened	Sherman	small	. . .	Parsons (1925)
Ripe	dye	.33	187	Giroud, Ratsimamanga, and Leblond (1935)
Ripe	Sherman	.10	57	Kohman, Eddy, and Zall (1930)
Peeled	Sherman	less	. . .	Cultrera (1933, 1935)
Skin and seeds	guinea pig	none	. . .	Vercellana (1924)
Juice	guinea pig	.10	57	Cultrera (1933, 1935)
Cooked	Sherman	.05	6	Hahn (1931)

No description	dye	.18	102	Chi and Read (1935)
No description	iodine	.30	170	Ditto
No description	Sherman	large amount	...	Cultrera (1933, 1935)
No description	dye	.13	74	Daggs and Eaton (1934)
No description	dye	.16	91	Dutcher, Guerrant, and Rasmussen (1935)
No description	Sherman	.20	113	Givens and McCluggage (1921)
No description	Sherman	.05	6	Hahn (1931)
No description	dye	small amount	...	Husseman (1937)
No description	Sherman	.13	74	Lepkovsky, Hart, Hastings, and Frazier (1925)
No description	dye	.25	142	Melka and Melkova (1936)
No description	dye	.32	181	Ranganathan (1935)
No description	guinea pig	.15	85	Rigobello (1928)
No description	dye	.39	221	Rudra (1936)
No description	dye	.35–.50	198–283	Sansome and Zilva (1933)
No description	Sherman	.01	6	Shorten and Ray (1921)
No description (13 samples)	dye	.13–.18	74–102	Daniel, Kennedy, and Munsell (1936)
No description (4 samples)	dye	.18–.36	102–204	McHenry (1935)
Canned Tomatoes				
English	Sherman	less than American	...	Kohman (1929)
Italian	guinea pig	none	0	Vercellana (1924)
Bonny Best	Sherman	.13	74	Spohn (1931)
Globe	Sherman	.13	74	Ditto
Stone variety (24 hours)	dye	.16–.18	91–102	Daniel and Rutherford (1936)
Stone variety (6 months)	dye	.11–.15	62–85	Ditto
Green	Sherman	.07	40	Kohman, Eddy, and Zall (1930)
Ripe	Sherman	.10	57	Ditto
Without air	Sherman	no loss	...	Kohman, Eddy, and Carlsson (1924)
Covered with salt brine	Bezssonoff reagent	.01	6	Remy (1928)
Boiling 1 hour pH 4.2	Sherman	50% loss	...	La Mer, Campbell, and Sherman (1921)
Boiling 4 hours pH 4.2	Sherman	70% loss	...	Ditto
15 pounds pressure for 30 minutes	Sherman	.05	28	Givens and McCluggage (1921)
Strained	dye	.13	74	Hanning (1936)
Strained (1 year)	guinea pig fed oats, hay, water	.10	57	Hess and Unger (1919)
Sieved	Sherman	.17	96	Kohman, Eddy, and Gurin (1933)
Canned (new)	Sherman	.06	34	Delf (1925)
Commercial	Sherman	equivalent of raw	...	La Mer (1921)
Commercial	Sherman	.09–.28	51–158	McHenry (1935)
Commercial (11 samples)	dye	.15–.25	85–142	Daniel, Kennedy, and Munsell (1936)
Commercial (35 samples)	dye	.07–.17	40–96	Rogers and Mathews (1938)
Commercial (sieved juice)	Sherman	.17	96	Fellers, Clague, and Isham (1935)
Commercial (3 years)	Sherman	.17	96	Givens and McCluggage (1921)
Commercial (3 years)	Sherman	.05	28	Ditto

TABLE 1.—ASCORBIC ACID CONTENT OF TOMATOES AND TOMATO PRODUCTS—PUBLISHED REPORTS—(*Continued*)

Description of Samples	Assay Method	Ascorbic Acid		Investigator
		Mg. per Gram	I. U. per Ounce	
Canned Tomatoes, Concluded				
Cold pack	dye	same as raw	. . .	Clow, Stevenson, and Marlatt (1929)
Open kettle	dye	1/3 of raw	. . .	Ditto
Home	Sherman	.13	74	Hoff (1933)
Home (sieved juice)	Sherman	.17	96	Fellers, Clague, and Isham (1935)
Home (tin)	dye	.18	102	Hauck (1938)
Home (glass)	dye	.09	51	Ditto
Home (43 samples)	dye	.09–.21	51–119	Rogers and Mathews (1938)
9 months	16-day guinea pig curative	.17	96	Clow and Marlatt (1930)
15-20 months	16-day guinea pig curative	.13	74	Ditto
Canned (4 years)	Sherman	.05	28	Delf (1925)
Conserve	Sherman	.05	28	Soloveichek (1935)
Recanned	Sherman	.17	96	Pilcher (1932)
No description	Bezssonoff reagent	.17	96	Bezssonoff and Van Wien (1934)
No description	guinea pig	markedly reduced	. .	Caro and Perling (1936)
No description	dye	.24	136	Dutcher, Guerrant, and Rasmussen (1935)
No description	Sherman	.17	96	Kohman, Eddy, and Gurin (1933)
No description	dye	.15	85	McHenry and Graham (1935)
No description	guinea pig	.12	68	Rigobello (1928)
Canned Tomato Juice				
Commercial (12 brands)	dye	.12–.32	68–181	Bailey (1937)
Commercial (25 brands)	dye	.12–.32	68–181	Bailey (1938)
Commercial (5 brands)	Sherman	.07–.13	40– 74	Fellers, Clague, and Isham (1935)
Commercial (average of 5 samples)	Sherman	.08	45	Kohman, Eddy, and Gurin (1933)
Home (5 samples canned in tin)	dye	.19–.22	108–125	Hauck (1938)
Home (5 samples canned in glass)	dye	.09–.11	51– 62	Ditto
Ethylene ripened	Sherman	.50	283	Jones and Nelson (1930)
Ripe	Sherman	.50	283	Ditto

Stone (24 hours)	dye	.16–.18	91–102	Daniel and Rutherford (1936)
Stone (6 months)	dye	.09–.16	51– 91	Ditto
Stone	Sherman	.10	57	Fellers, Clague, and Isham (1935)
Stone (homogenized)	Sherman	.08	45	Ditto
Marglobe (1933)	Sherman	.10	57	Ditto
Marglobe (homogenized)	Sherman	.10	57	Ditto
Marglobe (1934)	Sherman	.13	74	Ditto
Marglobe (concentrated to ½ volume in open kettle)	Sherman	.17	96	Ditto
Homogenized	Sherman	.17	96	Barnby and Eddy (1932)
Cold air cycloning, hot air sealing	Sherman	.10	57	Pilcher (1932)
Hot air cycloning, hot air sealing	Sherman	.10	57	Ditto
Cold air cycloning, warm vacuum sealing	Sherman	.13	74	Ditto
Cold vacuum cycloning, cold vacuum sealing	Sherman	.17	96	Ditto
Heated in shallow pan to remove oxygen	Sherman	.17	96	Kohman, Eddy, and Gurin (1933)
Vacuumized	Sherman	no loss	...	Hicks (1931)
Bottles sealed with corks and paraffin	dye	some loss	...	Husseman (1936)
No description	dye	.26	147	Ahmad (1935)
No description	Sherman	.17	96	Barnby and Eddy (1932)
No description	dye	.23	130	Bessey and King (1935)
No description	iodine	.27	153	Ditto
No description	dye	.21	119	Birch, Harris, and Ray (1933)
No description	Sherman	.13	74	Daggs and Eaton (1934)
No description	Sherman	.05–.08	28– 45	Delf (1925)
No description	dimethylamino-phenylindophenol	.24	136	Tauber and Kleiner (1935)
No description	dye	.18–.24	102–136	Tressler (1935)
No description	Sherman	.50	283	Williams (1924)
Puree	guinea pig	low	...	Izumrudova (1934)
Cocktail	Sherman	.17	96	Somers and Sweetman (1935)
Cocktail	Sherman	.19	108	Ditto
Cocktail	Sherman	.19	108	Ditto
Fermented Tomatoes				
Pickle	Sherman	negligible	...	Clow and Marlatt (1930)
Streptococcus lactis (7 days)	guinea pig	no destruction	...	Lepkovsky, Hart, Hastings, and Frazier (1925)
Streptococcus lactis (28 days)	guinea pig	partial destruction	...	Ditto
Dried Tomatoes				
Raw	Sherman	.50	283	Givens and McCluggage (1919)
No description	Sherman	.25	142	Givens and McCluggage (1921)
No description	Sherman	.15	85	Shorten and Ray (1921)
Sun	Sherman	.10	57	Ditto
Cooked and sun	Sherman	.10	57	Ditto
Paste (Humbert)	guinea pig	.50	283	Fomin and Makarova (1936)
Paste	guinea pig	.10	57	Ditto

fertilized. When soil moisture was adjusted from dry to very moist conditions, ascorbic acid was found to be somewhat lower under the dry conditions. The ascorbic acid content increased rapidly as moisture was supplied to the soil until the fruit approached 95 percent moisture when fully ripe. As more water was applied to the soil, the ascorbic acid content dropped off rapidly even though there was little or no change in the moisture content of the tomatoes. In 10 varieties of Italian tomatoes Cultrera (1933) found little relationship between ascorbic acid content and the sugar content, acids, or dry matter during ripening.

In a personal communication dated March 10, 1939, T. M. Currence of Minnesota Agricultural Experiment Station reports vitamin C content in terms of international units per ounce, mean of five plots, as follows: Marglobe 113, Valiant 124, Scarlet Dawn 110, Red Cap 106, All Red 120 and Harkness 102. He found a variation in Valiant variety from 105 to 140 units and in Red Cap 100 to 119. He points out that environmental factors in growth markedly affect vitamin C content but to a limited extent varietal differences do exist.

Krauss, Washburn, and Hoffman (1937) found that ascorbic acid was distributed in all parts of the tomato although it was not consistently high in the same part in all varieties. The placental tissue including the gelatinous material in which the seeds are embedded generally tends to be high in ascorbic acid. However, the epidermis is sometimes higher in ascorbic acid than the placental tissue. Cultrera (1933) found less ascorbic acid in peeled tomatoes than in whole tomatoes. Yet Vercellana (1924) found no ascorbic acid in the skin and seeds of the tomato.

Meager data by Krauss, Washburn, and Hoffman (1937) and Hoffman[3] on methods of ripening tomatoes, tend to show that diffused light develops more ascorbic acid than sunlight or darkness. Jones and Nelson (1930) found vine-ripened tomatoes to be better sources of ascorbic acid than either ethylene-treated or storage-ripened tomatoes. House, Nelson, and Haber (1929), using the Bonny Best variety, found that unripe tomatoes were relatively poor in ascorbic acid. Storage-ripened and ethylene-ripened tomatoes were richer than the green fruit, and vine-ripened tomatoes were superior to those ripened by either of the artificial methods. Clow, Stevenson, and Marlatt (1929) studying the commercial practice of ripening greenhouse tomatoes in an atmosphere of ethylene gas, concluded that this method seemed to increase the ascorbic acid content, but that such artificially ripened tomatoes were not quite so potent as tomatoes thoroughly ripened at room temperature. Clow and Marlatt (1930) commented that House, Nelson, and Haber (1929) used only a 4-gram level in feeding guinea pigs. This is a high level where minimum recovery dosage is reported. Using a lower level of feeding, Clow and Marlatt (1930) showed that ascorbic acid develops practically to the same extent whether the ripening takes place on the vine, in a dark room, in a light room, or in an atmosphere of ethylene gas. Their studies confirm those of House, Nelson, and Haber (1929) in showing that there is an increase in ascorbic acid during the ripening process. Also ethylene ripening, though not destructive to ascorbic acid, may inhibit its development in the tomato.

Canned Tomatoes

Conflicting reports have been published on the stability of ascorbic acid during the canning processes. The lack of standardized procedure in canning is no doubt a major factor in explaining these discrepancies.

La Mer (1921) compared one lot of commercially canned tomatoes with raw tomatoes grown in his own garden and found the canned equivalent to the raw in ascorbic acid content. Kohman, Eddy, and Zall (1930) found that canned tomatoes protected guinea pigs from scurvy as well as did the fresh fruit. Clow and Marlatt (1930), using the 16-day recovery method, reported that cold-packed canned tomatoes contained the same amount of ascorbic acid as the raw tomato. Delf (1925), an English investigator, found that the canning of tomatoes destroyed about 75 percent of the ascorbic acid; but Kohman (1929) stated that the English canning method is not the commercial method employed in America and, consequently, differences in results are to be expected. Vercellana (1924) reported that preserved tomatoes contained no ascorbic acid. Caro and Perling (1936) found that the ascorbic acid of canned tomatoes varied greatly from that of the fresh product. All of these experiments were conducted by biological methods which are not sensitive to the small differences detected by the chemical test, but the larger differences mentioned cannot be accounted for by the limitations of the method used.

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[3] Hoffman, I. C., 1937. Personal communication.

Rogers and Mathews (1938) found, by chemical tests, that commercial and home-canned tomatoes each contained 0.14 mg. of ascorbic acid per cc. Daniel and Rutherford (1936) compared the canning of tomatoes in tin cans and glass jars. The loss due to the canning was 12 percent in the tin cans and 21 percent in the glass jars. They also found that storage of canned tomatoes over a period of 6 months destroyed from 10 to 23 percent of the ascorbic acid. Clow and Marlatt (1930) and Hess and Unger (1919) found only a slight loss after one year's storage. Delf (1925) reported 5 percent loss in four years' storage at laboratory temperature. Hanning (1936), investigating canned strained tomatoes, found marked variation in ascorbic acid content of the crops of four successive years.

Canned Tomato Juice

La Mer, Campbell, and Sherman (1921) studied the effect of heating upon the destruction of ascorbic acid in tomato juice. They measured the percentage loss in open containers for periods of one to four hours at 60°, 80°, and 100° C. The velocity of destruction in the experiments decreased with the time and in a greater degree than would be expected if the reaction followed the monomolecular reaction law. The percentage of ascorbic acid destroyed was found to vary empirically as the fourth root of the time. The reaction was not appreciably sensitive to ordinary light. The velocity of most chemical reactions is at least doubled for each increase in temperature of 10° C. Delf (1925) first pointed out that ascorbic acid does not follow this law. La Mer (1921) found that between 60° and 80° C., a rise in temperature of 10 degrees caused only 1.2 times more destruction of ascorbic acid for a given period. Between 80° and 100 ° C., a rise in temperature of 10 degrees increased the destruction only 1.1 times. Convincing data that oxidation is the major factor causing destruction and that ascorbic acid is relatively stable toward heat has been presented by Kohman, Eddy, and Carlsson (1924). They showed that when the oxygen was removed from apples by the respiratory process these apples could be canned without any loss of ascorbic acid. This evidence may well be considered by manufacturers of tomato juice. Tomatoes for juice are heated at a high temperature over a period of time to soften the flesh and then are forced or cycloned through a fine screen. At this stage of the process air may be entrapped in the juice, causing subsequent oxidation and destruction of ascorbic acid.

Hicks (1931) found that vacuumization during cycloning resulted in maximum ascorbic acid retention. Pilcher (1932) stated that air-cycloned, cold tomato juice may be effectively de-aerated by warm vacuumization before canning. Kohman, Eddy, and Gurin (1933) showed that when the freshly expressed juice is quickly heated to boiling in shallow layers, the inert gases present scrub out the oxygen. Naturally, destruction of ascorbic acid by oxidation is diminished. Barnby and Eddy (1932) and Fellers, Clague, and Isham (1935) were unable to demonstrate any losses in tomato juice due to mechanical dispersion by homogenization. The juices obtained by straining either home-canned or commercially canned tomatoes through a sieve compared favorably with the best commercially canned tomato juices according to Fellers, Clague, and Isham (1935). The Marglobe variety of tomato yielded juice of a somewhat higher potency than the Stone variety. These investigators correlated a pleasing taste with the ascorbic acid content of commercially canned tomato juices, all but one of which were satisfactory antiscorbutics. They also found considerable annual variation in the brands. A Connecticut Experiment Station Food Products Report (Bailey, 1937) indicated a variation of from 0.12 to 0.32 mg. of ascorbic acid per gram in 12 samples of commercially canned tomato juice. A report by Bailey (1938) showed the same variation in 25 samples of commercially canned tomato juice.

Barnby and Eddy (1932) found no differences in the ascorbic acid content of the same batch of tomato juice canned in tin and glass containers. Husseman (1936) reported that tomato juice in bottles, sealed with corks and paraffin, lost a part of its potency to prevent scurvy. The shape of the bottle and type of glass did not influence losses. Hauck (1938) and Daniel and Rutherford (1936) found that ascorbic acid losses were greater when the juice was canned in glass than when canned in tin. Also storage loss was greater in glass jars than in tin containers.

METHODS USED IN DETERMINING ASCORBIC ACID IN TOMATOES AND TOMATO PRODUCTS

Biological

Following the method of Sherman, La Mer, and Campbell (1922), young guinea pigs, weighing from 250 to 350 grams each, were fed the basal diet and water ad libitum. This diet, generally accepted as adequate except for ascorbic acid, consisted of the following ingredients:

Baked skimmed milk powder	15.00 parts
Rolled oats	14.75 "
Bran	14.75 "
Butter	4.50 "
Cod liver oil (not included in the Sherman diet)	0.50 "
Sodium chloride	0.50 "

The animals were housed in individual cages with raised bottoms made of ¼-inch sand screen to allow the droppings to pass through into trays below.

The material to be tested for ascorbic acid was fed daily, six times a week, for a period of 90 days. Three animals were placed on each level of feeding as a check in case one animal became ill from causes other than ascorbic acid deficiency.

Autopsies were performed on all animals at death. If the animal survived the 90-day feeding period, it was chloroformed and the autopsy then performed. The severity of the scurvy lesions was scored according to an arbitrary system proposed by Sherman et al. (1922). This numerical score is based on autopsy findings of weakness in the bony system (joints, ribs, jaw, and teeth) and hemorrhages in joints, ribs, muscles, and intestines. One, two, or three plus signs are recorded for each of the eight parts examined, according to the degree of abnormality found, thus making possible a maximum scurvy score of 24. Isham (1932) noted in examining guinea pigs, that hemorrhages of the bladder were often found in cases of scurvy, but absent in all other instances. This characteristic lesion should be taken into account in scoring the hemorrhages of the intestine. Isham (1932) also noted that much less variation in results occurred when the full 90-day feeding period was used.

Negative controls, which received the basal ration only, died from scurvy in from 23 to 36 days. Positive controls were also used for comparison, the animals receiving two grams of grapefruit juice daily. These positive control guinea pigs usually doubled their weight and showed no evidence of scurvy lesions.

Chemical

Of the many procedures mentioned in the literature for chemical estimation of ascorbic acid, only two are used in this study of the tomato and tomato products. Data on the modified iodine titration technic of Lorenz, Reynolds, and Stevens (1934) and Stevens (1938) have not been reported to any extent. Consequently, it was thought best to study this method to prove definitely its value. The 2, 6-dichlorophenolindophenol dye suggested by Tillmans, Hirsch, and Hirsch (1932) is accepted to date as the most accurate quantitative method for determining ascorbic acid. Therefore, this dye was used in this study.

Modified Iodine Titration for Ascorbic Acid

Extracted serum from the material to be tested for ascorbic acid was acidified with 12N sulfuric acid. Standardized 0.01N iodine solution containing 25 grams of potassium iodide per liter was added until an excess was indicated by a brown color. Standardized 0.01N sodium thiosulfate solution was added in slight excess, followed by a small quantity of 0.5 percent starch solution. Finally, more of the 0.01N iodine solution was added slowly until the well-known starch–iodine end point was reached. Calculation for ascorbic acid content of the sample was as follows:

Total I_2 volume less I_2 equivalent of $Na_2S_2O_3$ volume =
volume I_2 for the oxidation of ascorbic acid.

This procedure differs from the ordinary iodine technic in two essential respects. The modified iodine method has a higher acidity and there is a double back titration. If sufficient sulfuric acid is not added, the titration will be sluggish, especially near its completion. When sufficient acid is present, the end point persists for a longer period of time. Furthermore, at the lower pH, the iodine oxidizes less of the reducing substances, other than ascorbic acid, which may be present.

Dye Titration for Ascorbic Acid

Extracted serum from the sample was adjusted approximately to neutrality according to the method of Tillmans, Hirsch, and Hirsch (1932), by the addition of sodium acetate. Standardized 0.05 percent 2, 6-dichlorophenolindophenol was added until oxidation of the ascorbic acid was complete. This was indicated by the excess of dye which was blue in neutral solutions. The total volume of dye utilized is a measure of a part of the reducing capacity of the tested material. This portion of the reducing capacity of plant substances is closely correlated with the ascorbic acid content.

ADAPTATION OF TITRATION METHOD TO THE DETERMINATION OF ASCORBIC ACID IN TOMATOES AND TOMATO PRODUCTS[4]

Method of Extraction

Harris and Ray (1933) found that enzymatic oxidation of ascorbic acid takes place in neutral solutions. At the normal pH of most plant materials, this also occurs when the tissue cells are macerated and exposed to the air. They suggested that the method of Tillmans, Hirsch, and Hirsch (1932) be modified by lowering the pH of the medium to 2.5 by the addition of strong acetic acid. This acidification reduces enzymatic oxidation of ascorbic acid. Bessey and King (1935) found that trichloroacetic acid is preferable to acetic acid as an extracting medium.

The comparative efficiencies of hot 8 percent acetic and 3 percent trichloroacetic acids for extracting ascorbic acid from tomato tissue were determined, with 2, 6-dichlorophenolindophenol dye as the oxidizing agent to determine the amount of ascorbic acid extracted. The more constant and representative results were obtained by using trichloroacetic acid. The average maximum variation on five samples of tomato juice extracted with trichloroacetic acid was 1.89 percent and for hot 8 percent acetic acid was 5.24 percent.

Fujita and Iwatake (1935) have demonstrated the advantage of 2 percent metaphosphoric acid for the extraction of ascorbic acid. The advantage is the elimination of the slow oxidation of ascorbic acid which occurs when trichloroacetic acid is the sole acidifying medium. Musulin and King (1936) and Mack and Tressler (1937) indicated consistent results with a mixture of 3 percent trichloroacetic acid and 2 percent metaphosphoric acid. This combination has the advantages of both acids as an ascorbic acid extracting medium. With this mixture, the cellular structures in some tissues are disrupted more rapidly by trichloroacetic acid while the metaphosphoric acid prevents the slow oxidation by the trichloroacetic acid and also exerts a better deproteinizing action.

The substitution of 1N, 2N, 3N, or 4N sulfuric acid for trichloroacetic acid in the acid mixture was suggested by Thornton (1938) after the present investigation had been completed. Basing his work on that of Mack and Tressler (1937), he finds that only strong acids inactivate the ascorbic acid oxidizing enzymes found in plant tissue. Also, suitable concentrations of sulfuric acid eliminate the necessity of later treating the tissue extract with hydrogen sulfide to recover ascorbic acid which may have been oxidized.

Number of Extractions

The usual method of extracting ascorbic acid from plant tissue consists of a contact period with the acid mixture, separating the color by centrifugal force, and decanting the clear serum. It is desirable to know whether one extraction of this serum is sufficient to obtain all of the ascorbic acid present in the tomato. The residual ascorbic acid extracted from 24 samples of tomatoes on making a second extraction was 8.3 percent. A third extraction, although usually impractical on routine samples, showed residue of about 1.5 percent.

A somewhat higher ascorbic acid content was found in tomato juice after one extraction. The average increase in 8 juice samples was 15.6 percent.

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[4] For details of experimental methods and results see Maclinn (1938).

Dye Indicator Strength

It has been suggested by some investigators that a 0.1 percent 2, 6-dichlorophenolindophenol dye solution, instead of the usual 0.05 percent solution, will result in closer titration values for ascorbic acid. To determine the accuracy of this suggestion, the sera extracted from ten centrifuged 50 cc. samples of tomato juice were diluted to 100 cc. each. Three aliquot portions were titrated for ascorbic acid with 0.05 and 0.10 percent dye solutions. The results show that in five samples of tomato juice an average maximum variation of 2.87 percent was found with the 0.10 percent concentration of dye and 6.04 percent with the 0.05 percent dye concentration. That is, much greater accuracy is obtained by the use of the stronger dye.

Probable Error

In any chemical titration there is an element of error in determining the end point. To establish this value in both the modified iodine and the 2, 6-dichlorophenolindophenol methods the following equation was used:

$$\text{probable error} = \pm 0.6745 \sqrt[2]{\frac{\Sigma d^2}{n^2}}$$

where Σd^2 is the summation of the squares of the deviations from the arithmetical mean, and n^2 is the square of the number of determinations.

The acid-extracted supernatent liquid from centrifuged tomato juice was used to determine the probable error in reading the end point. The serum from 50 cc. of juice was made up to 100 cc. and titrated in aliquot portions of 25 cc. Ten samples of juice titrated in triplicate, a total of 30 titrations, were used for the 0.10 percent dye method and 30 titrations for the iodine method. The results show a probable error of ±.05 cc. on the three successive titrations of each sample. A variation of ±.05 cc. in each titration of a tomato sample which averages 3 cc. of dye, gives a probable error of ± 2 percent on each sample. Under like conditions the probable error in determining the titration end point in the iodine method was only ±.02 cc. These data show that uniform results can be obtained by using chemical titration methods for determining ascorbic acid with only slight error.

Standardization of the Dye

Early literature on the estimation of ascorbic acid by the chemical titration method is reported in terms of quantity of the dye reduced. When crystalline ascorbic acid was finally synthesized, it became possible to standardize the dye solution in terms of the pure acid. This eliminated the necessity of preparing fresh solutions of the dye daily. However, for accurate quantitative work, it is considered inadvisable to use dye solutions made up for periods longer than five days.

The method of standardizing the 2, 6-dichlorophenolindophenol dye against pure ascorbic acid is not accurate at best. Besides being expensive, the small quantities of the pure acid used may lead to inaccuracies in the standardization. Moreover, aqueous solutions of pure ascorbic acid are rapidly oxidized in the atmosphere; this necessitates rapid titration of the dye.

Birch, Harris, and Ray (1933) suggested that the ascorbic acid be standardized with iodine to eliminate the possible error caused by the presence of impurities in the ascorbic acid. One molecule of ascorbic acid reduces two atoms of iodine.

Bessey and King (1935) preferred the standardization of the unstable aqueous solutions of ascorbic acid with iodine, using the iodine solution as a stock reference. Iodine solutions stored in dark glass containers at cool temperatures are relatively stable; at least, they are less subject to error than the fresh ascorbic acid solutions prepared daily. Lemon juice, an acid medium that protects the ascorbic acid of the fruit from atmospheric oxidation, is standardized with the stock iodine solution and in turn standardizes the 2, 6-dichlorophenolindophenol dye. This appears to be a complicated procedure and subject to possible error, but, with the small probable error of titration and the stability of the acid lemon juice, the standardization of the dye solution is considered reliable. This is the method finally adopted for this work. However, very recently Buck and Ritchie (1938) and also Menaker and Guerrant (1938) have shown that the dye is very easily and accurately standardized by the use of standard thiosulfate and iodine solutions.

Interfering Substances

Harris and Ray (1933) contended that acidifying the sample prevents reduction of the dye by substances other than ascorbic acid and the amino acid, cysteine. However, Szent-Györgyi and Svirbely (1932, 1933) found that when titration is rapid cysteine does not interfere with the determination. It is therefore assumed that ascorbic acid can be determined in the tomato without special preparation to remove possible interfering materials.

Not all investigators are content to depend on rapid titration. Tauber and Kleiner in 1935 proposed a method in which ascorbic acid is destroyed by a specific enzyme. This is an alcohol-soluble oxidase found in Hubbard and summer squash. The method is based on the theory that the reducing value after the ascorbic acid has been destroyed is due to interfering substances.

Crystalline ascorbic acid was used experimentally to test the accuracy of this method. In brief, the results obtained were neither consistent nor accurate and the method was discarded as unsuitable.

Reversibly Oxidized Ascorbic Acid

Tillmans, Hirsch, and Hirsch (1932) found that ascorbic acid may be oxidized to a reversible form which is antiscorbutically active but is not determinable by the usual chemical titration method. Tillmans, Hirsch, and Dick (1932) reduced this reversible form of oxidized ascorbic acid with hydrogen sulfide, scrubbed out the latter with an inert gas, and then continued the titration by the regular method.

Using commercially canned tomato juice and the juice of raw tomatoes, experimental results show the absence of oxidized ascorbic acid in both products. Storage of these juices for 26 hours in open containers resulted in an apparent loss of 30 percent of the ascorbic acid. On reduction of the stored juices with hydrogen sulfide, the actual loss of ascorbic acid was found to be only about 10 percent. That is, approximately 20 percent of the ascorbic acid present in these juices was reversibly oxidized by standing in open containers at room temperature for 26 hours.

Effect of Dissolved Iron and Tin

Acid foods preserved in tin cans normally contain stannous and ferrous ions that have been dissolved from the metal container. Since this study includes preserved as well as fresh products, it is desirable to know whether these ions react with the oxidizing agents used for the determination of ascorbic acid. Samples of juice expressed from raw tomatoes without contacting any metal were used to determine the effect of metallic ions. Results show that 1 or 100 parts per million of either stannous or ferrous ions or 200 parts per million of both, in tomato juice do not interfere with the chemical determination of ascorbic acid. However, if the end point is not reached and read promptly during the titrations the metallic ions obscure the end point and make it difficult to obtain a true reading. Normal solutions of either or both ions do not react with the 2, 6-dichlorophenolindophenol dye used in the titration. Thus the presence of iron and tin salts in foods canned in tin containers does not interfere with the titration of ascorbic acid.

DESCRIPTION OF PERFECTED CHEMICAL TITRATION METHOD FOR DETERMINATION OF ASCORBIC ACID

Preparation of indicator solution (0.10 percent).

1. Dissolve approximately 0.10 gram of dry 2, 6-dichlorophenolindophenol indicator with successive portions of warm water, filter, and add water to make up to a volume of 100 cc.
2. Do not store for periods longer than five days.
3. Standardize indicator solution daily.

Preparation of iodine solution (0.01N).

1. Dissolve approximately 1.3 grams of iodine and 25 grams of potassium iodide in distilled water and make up to one liter.
2. Store iodine solution in a dark or paper wrapped bottle at ordinary refrigerator temperature.

Preparation of sodium thiosulfate solution (0.01N).

1. Dissolve 25 grams of sodium thiosulfate in distilled water and make up to a liter. This makes a 0.10N stock solution.
2. Dilute ten times to prepare a 0.01N solution.

Preparation of starch solution (0.5 percent).

1. Dissolve 0.5 gram of soluble starch in 100 cc. of cold water and store at a cold temperature.

Preparation of acid mixture (3 percent trichloroacetic acid and 2 percent metaphosphoric acid).

1. Dissolve 30 grams of trichloroacetic acid and 20 grams of metaphosphoric acid in one liter of water.

Standardization of iodine solution against pure ascorbic acid.[5]

1. Accurately weigh about 10 mg. of pure ascorbic acid.
2. Dissolve in acid mixture and make up to 100 cc. volume with acid mixture.
3. Dilute three 10 cc. aliquot portions of ascorbic acid solution with 25 cc. of acid mixture.
4. Add 5 to 10 drops of starch solution to each portion.
5. Add iodine solution from a burette until the blue starch–iodine color appears, indicating the end point.
6. Repeat the above procedure until the amount of iodine reduced by three samples checks closely.
7. Standardize the iodine solution bi-monthly.

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[5] While this method of standardization was followed in all of the determinations reported in this bulletin, the authors now recommend the use of standard iodine and thiosulfate solutions as described by Buck and Ritchie (1938) and also by Menaker and Guerrant (1938). The data reported in this bulletin were largely obtained before the publication of this technic.

Example of Calculation

Weight of ascorbic acid — 12.5 mgs.

Weight of ascorbic acid in 10 cc. aliquot — 1.25 mgs.

0.77 cc. iodine = 1.25 mgs. ascorbic acid.

1 cc. iodine = 1.62 mgs. ascorbic acid.

Standardization of 2, 6-dichlorophenolindophenol dye.

1. Dilute 2 cc. of lemon juice with 20 cc. of water.
2. Add dye solution from burette until a pink end point is continuous for one minute.
3. Repeat until results check.

Example of Calculation

2.64 cc. indicator = 2 cc. lemon juice.

1.32 cc. indicator = 1 cc. lemon juice.

4. Dilute 5 cc. of lemon juice with 20 cc. of water and add 5 to 10 drops of starch solution.
5. Add iodine solution from burette until blue starch–iodine color appears.
6. Repeat until results check.

Example of Calculation

1.81 cc. iodine = 5 cc. lemon juice.

1 cc. iodine = 2.76 cc. lemon juice = 1.620 mgs. ascorbic acid (from standardization of iodine).

2.76 cc. lemon juice = 3.64 cc. indicator = 1.620 mgs. ascorbic acid.

1 cc. indicator = 0.445 mg. ascorbic acid.

Summary: Indicator = lemon juice = iodine = ascorbic acid.

Preparation of sample from fresh tomatoes.

1. Accurately weigh a cross section or quarter section of approximately 25 grams.
2. Thoroughly triturate sample in a mortar with about 5 grams of acid-washed white sand and 50 cc. of the acid mixture.
3. Pour into centrifuge tubes.
4. Rinse out mortar with more of the acid mixture and pour into the same tubes.
5. Centrifuge at 1800 revolutions per minute for 15 minutes.
6. Decant serum (colorless liquid) from centrifuge tubes into a 200 cc. volumetric flask.
7. Cover residue in centrifuge tubes with acid mixture and extract a second time by centrifuging for same period of time and speed.
8. Decant serum into previous extraction. Make up to 200 cc. volume with acid mixture.
9. Titrate 25 cc. aliquot portions of this 200 cc. volume with the 2, 6-dichlorophenolindophenol dye. The pink end point should persist for one minute.
10. Make three separate titrations.

Example of Calculation

Weight of sample — 36.7 gms.

Weight of sample in 25 cc. aliquot — 4.59 gms.

3.19 cc. indicator = 4.59 gms. tomato.

1 cc. indicator = 1.48 gms. tomato.

1.48 gms. tomato = 0.445 mg. ascorbic acid (from standardization of the indicator).

1 gm. tomato = 0.301 mg. ascorbic acid.

Preparation of sample from tomato juice.

1. Place 25 cc. of tomato juice in each centrifuge tube. Add 10 cc. of acid mixture to each sample.
2. Centrifuge at 1800 revolutions per minute for 15 minutes.
3. Decant serum into a 200 cc. volumetric flask.
4. Cover residue in centrifuge tubes with acid mixture and extract a second time by centrifuging for same period of time and speed.
5. Decant serum into previous extraction. Make up to 200 cc. volume with acid mixture.
6. Titrate 25 cc. aliquot portions of this 200 cc. volume with the 2, 6-dichlorophenolindophenol dye. The pink end point should persist for one minute.
7. Make three separate titrations.

Example of Calculation

Amount of tomato juice — 25 cc.
Amount of tomato juice in 25 cc. aliquot — 3.13 cc.
0.68 cc. indicator = 3.13 cc. tomato juice.
1 cc. indicator = 4.60 cc. tomato juice.
4.60 cc. tomato juice = 0.445 mg. ascorbic acid (from standardization of the indicator).
1 cc. tomato juice = 0.096 mg. ascorbic acid.

COMPARISON OF DYE, MODIFIED IODINE, AND BIOASSAY METHOD FOR DETERMINING ASCORBIC ACID

Tests were made to show how close a correlation existed between the chemical titration methods and the more time-consuming animal-feeding method.

The contents of two cases of 14-ounce cans of a commercial brand of tomato juice were thoroughly mixed in one batch, heated to 170° F., sealed in No. 1 tin containers and sterilized in boiling water for 15 minutes. As it took no more than ten minutes to seal the entire lot of cans, they were considered uniform in every particular. Slight differences in headspace and temperature may have occurred. Three guinea pigs were placed on each feeding level of 4.50, 4.75, 5.00, 5.25, 5.50, 5.75, 6.00, 6.50, 7.00, 7.50, and 8.00 cc. daily. With the three negative controls and the three positive controls, this made a total of 39 animals on the experiment. Daily titrations by both the iodine and the dye methods were made on the identical cans from which the animals were fed. Tomato juice supplemented the basal diet of Sherman, La Mer, and Campbell (1922) over the 90-day feeding period. The results of the chemical titrations and the animal feedings are reported in Tables 2 and 3. The pertinent animal data are reported in Figure 1.

The results show that the daily protective level for guinea pigs on this recanned tomato juice was 6.7 cc. Unpublished data in this laboratory show that 0.6 mg. of pure ascorbic acid is the daily protective level of a young, growing 300 to 400 gram guinea pig. Calculating from this, it is seen that this tomato juice contained 0.09 milligrams of ascorbic acid per cc. or 51 units per ounce. By the 2, 6-dichlorophenolindophenol chemical method, this sample of tomato juice was shown to contain 51 units per ounce. The modified iodine method gave 74 units per ounce.

This experiment shows that the chemical method, as described in detail, is reliable for determining ascorbic acid. The 2, 6-dichlorophenolindophenol dye method for determining ascorbic acid is used in all the following tomato investigations as it corresponds more closely to the biological values. When the modified iodine method is used, all figures must be multiplied by the factor 0.7.

Table 2.—Comparison of Dye and Modified Iodine Methods for Determining Ascorbic Acid in Recanned Tomato Juice

Storage Period Days	Number of Samples*	*Ascorbic Acid, Average Mg. per Cc.	
		Dye Method	Modified Iodine Method
1– 30	30	.09	.12
31– 60	30	.09	.12
61– 90	30	.08	.13
91–121	31	.09	.13
Average		.09	.13

*Titrations were made daily, and 3 determinations were made on each sample.

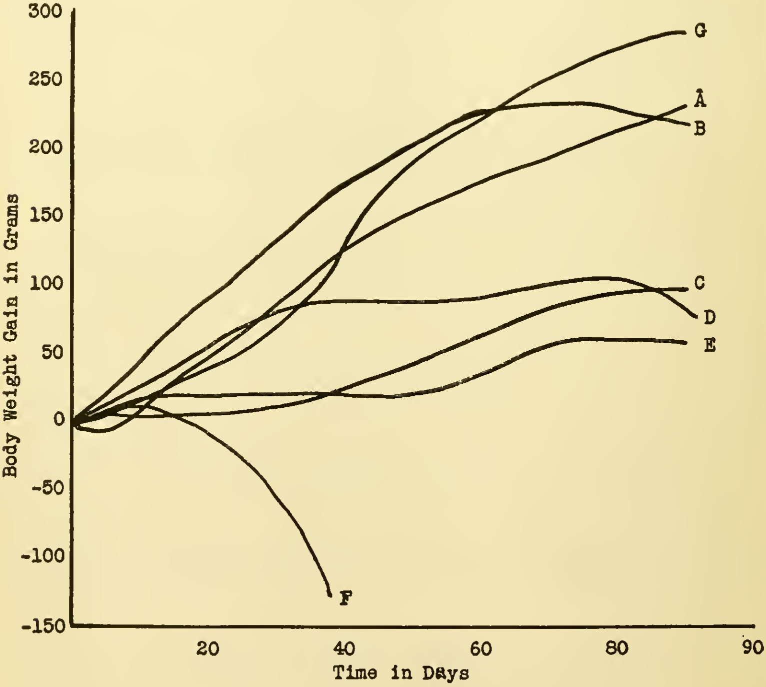

Figure 1. Biological Assay for Ascorbic Acid in Recanned Tomato Juice. Weight gains and scurvy scores of guinea pigs.

	Tomato Juice Fed	Scurvy Score
A	7.50 cc.	0
B	7.00 cc.	0
C	6.50 cc.	1.8
D	5.75 cc.	3.2
E	5.00 cc.	4.2
F (negative control)	none	11
G (positive control) fed 3 cc. canned grapefruit juice		0

TABLE 3.—BIOLOGICAL ASSAY OF ASCORBIC ACID IN RECANNED TOMATO JUICE

Amount Fed Daily* cc.	Average Change in Weight Grams	Average Survival Period Days	Average Scurvy Score
4.50	6	61	5
4.75	74	62	5
5.00	55	64	4.2
5.25	35	60	5.8
5.50	129	72	2.8
5.75	75	79	3.2
6.00	162	90	1.6
6.50	90	90	1.8
7.00	227	90	0
7.50	240	90	0
8.00	199	90	0
0.00 (negative control)	—127	36	11

*Three animals were fed at each level.

STUDY OF ASCORBIC ACID IN RAW TOMATOES[6]

Effect of Variety and Strain[7]

Ninety-eight strains and varieties of tomatoes were grown on experimental plots. In most cases the source of the seed is indicated. All had exactly the same fertilizer treatments and care. Six samples of each variety or strain were used, each sample consisting of a composite portion, 25 to 50 grams, of a firm, ripe tomato from a different plant of each separate variety. Data show that a second extraction of tomato gives an average increase of 10 percent in the total determined content of ascorbic acid. Therefore, 10 percent was added to the values obtained on the 98 varieties and strains and the total expressed both in milligrams of ascorbic acid per gram of tomato, and as international units per ounce (Table 4).

The results show considerable variation in the ascorbic acid content of tomato varieties. Because of this variation, due consideration should be given to variety when comparing tomatoes to other products containing the antiscorbutic factor.

Hahn and Görbing (1933) found that fertilizer constituents influenced the amount of ascorbic acid in spinach. The differences in ascorbic acid content of tomato varieties cannot be attributed to the fertilizer in this experiment, as all varieties received the same nutrients and care. The soil on all experimental plots was of the same type, sandy loam.

Ten varieties contained 200 or more units per ounce. These are truly excellent sources of ascorbic acid and compare very favorably with oranges or grapefruit. Among the varieties are several new strains developed by the Massachusetts Field Station at Waltham, Massachusetts. Forty-eight varieties or strains, about one-half of the total, yielded between 150 and 200 units per ounce. A number of the leading commercial varieties are grouped in the range 140 to 185 units per ounce. Attention is called to variations found among different fruits of the same variety. Definite conclusions cannot be drawn because of this variation. It is possible that tomatoes produced under other conditions might give different results.

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[6] Acknowledgement is gratefully made to Professor G. B. Snyder of the Olericulture Department, who supervised the collection of seeds and the culture of the tomatoes.

[7] For a preliminary report see Maclinn, Fellers, and Buck (1937).

TABLE 4.—ASCORBIC ACID CONTENT OF 98 VARIETIES AND STRAINS OF TOMATOES (1936 CROP)

Plot	Variety	Ascorbic Acid Milligrams per Gram			Equivalent International Units per Ounce
		Maximum	Minimum	Mean and S. D.*	
6E	Greenhouse, No. 9-1936	.50	.41	.44 ± .03	249
13A	Golden Nugget, Sutton	.50	.31	.43 ± .02	243
8A	Princess of Wales, Sutton	.59	.30	.41 ± .09	232
6	Mass. Field Station, No. 7-1	.58	.29	.41 ± .09	232
11	Ideal Forcing, Grand Rapids	.47	.30	.39 ± .06	221
5	Mass. Field Station, No. 2-1	.50	.30	.39 ± .08	221
6B	Mass. Field Station, No. 11-1	.54	.31	.39 ± .07	221
6A	Mass. Field Station, No. 8-1	.49	.29	.37 ± .05	209
8B	Best of All, Sutton	.51	.26	.36 ± .09	204
6C	Mass. Field Station, No. 13-1	.43	.28	.36 ± .05	204
29	John Baer, Ferry-Morse	.48	.29	.35 ± .06	198
4	Mass. Field Station x Market Garden Field Station	.58	.24	.35 ± .11	198
3	Comet, Perry	.37	.33	.35 ± .02	198
37	Bonny Best, F. H. Woodruff	.50	.23	.34 ± .08	192
1	Comet, Forbes	.39	.30	.33 ± .04	187
42	Early Stone, Harris	.41	.27	.33 ± .05	187
41	Rosy Morn, Livingston	.51	.19	.33 ± .10	187
83	Red Pear, Eastern States	.36	.27	.32 ± .03	181
16	Lange's Earliana, Stokes	.46	.18	.32 ± .09	181
17	Sparke's Earliana, Burpee	.44	.24	.32 ± .07	181
6D	Mass. Field Station, No. 15-1	.35	.27	.31 ± .03	175
86	Red Plum, Comstock-Ferre	.33	.29	.31 ± .01	175
31	Special Bonny Best, Burrell	.38	.23	.31 ± .06	175
67	Greenhouse Forcing, 6-876, Stokes	.37	.22	.31 ± .05	175
38A	Brown's Special (Certified)	.43	.25	.31 ± .06	175
61	Master Marglobe, F. H. Woodruff	.37	.27	.31 ± .03	175
47	Stone, Certified, F. H. Woodruff	.40	.21	.31 ± .06	175
62A	Marglobe, Abbott and Cobb	.38	.24	.31 ± .03	175
43	New Stone, F. H. Woodruff	.37	.21	.30 ± .06	170
32	Reselected Bonny Best, Comstock-Ferre	.36	.37	.30 ± .04	170
6F	Mass. Field Station x Baltimore No. 11 Fall 1935	.43	.18	.30 ± .09	170
49	Greater Baltimore, F. H Woodruff	.38	.24	.30 ± .04	170
46	Stone, Livingston	.46	.22	.30 ± .08	170
66	Marglobe, Livingston	.39	.22	.30 ± .05	170
22	Special Earliana, Platt	.39	.24	.29 ± .05	164
9	Lister's Protection, Grey	.42	.23	.29 ± .07	164
44	Stone, Burpee	.40	.23	.29 ± .06	164
76	Italian Red Pear, Harris	.45	.18	.29 ± .08	164
34	Bonny Best, Harris	.32	.22	.29 ± .03	164
7	Double Purpose, Forbes	.44	.24	.29 ± .07	164
2	Comet, Grey	.38	.22	.29 ± .05	164
39	Chalk's Early Jewel, Comstock-Ferre	.40	.19	.29 ± .07	164
69	Rutgers, Forbes	.37	.24	.29 ± .04	164
33	Bonny Best, Ferry-Morse	.36	.21	.29 ± .05	164
24	Avon Early, Ferry-Morse	.37	.22	.28 ± .05	158
65	Marglobe, Forbes	.36	.22	.28 ± .04	158
18	Sunnybrook Earliana, Burpee	.41	.23	.28 ± .06	158
40	Chalk's Early Jewel, Grey	.33	.26	.28 ± .03	158
28	John Baer, Eastern States	.37	.19	.28 ± .06	158
56	Markio, Forbes	.34	.23	.28 ± .03	158

*Standard Deviation from the mean.

Table 4.—Ascorbic Acid Content of 98 Varieties and Strains of Tomatoes (1936 Crop)—*Continued.*

Plot	Variety	Ascorbic Acid Milligrams per Gram			Equivalent International Units
		Maximum	Minimum	Mean and S. D.*	per Ounce
15	Earliana, Forbes	.35	.19	.28 ± .06	158
8C	Spring Garden, Abbott and Cobb	.46	.19	.28 ± .03	158
58	Globe, Livingston	.36	.17	.27 ± .09	153
30	John Baer, Harris	.29	.26	.27 ± .01	153
21	Selected Earliana, Forbes	.36	.20	.27 ± .05	153
79	Pritchard, Livingston	.41	.19	.27 ± .07	153
8	Belmont Improved, Grey	.35	.20	.27 ± .05	153
73	N. Y. State, Comstock-Ferre	.32	.19	.26 ± .05	147
71	Rutgers, Stokes	.37	.18	.26 ± .07	147
63	Marglobe, Burpee	.30	.19	.26 ± .05	147
50	Indiana Baltimore, F. H. Woodruff	.32	.18	.26 ± .05	147
53	Golden Queen, Livingston	.30	.22	.26 ± .03	147
12	Michigan State Forcing, Grand Rapids	.39	.20	.26 ± .07	147
19	Penn. State Earliana, Burpee	.35	.20	.26 ± .05	147
25	Clarks Early, F. H. Woodruff	.30	.21	.26 ± .04	147
45	Stone, Eastern States	.28	.23	.26 ± .02	147
48	Success, Harris	.29	.21	.26 ± .03	147
27	Scarlet Dawn, Platt	.35	.21	.26 ± .05	147
51	Baltimore, Stokes	.33	.23	.26 ± .04	147
38	Super Standard Bonny Best, Stokes	.33	.19	.25 ± .06	141
70	Rutgers, Perry	.38	.19	.25 ± .06	141
36	Bonny Best, Shirley	.29	.23	.25 ± .03	141
64	Marglobe, Eastern States	.30	.21	.25 ± .03	141
10	Grand Rapids Forcing, Grand Rapids	.35	.21	.25 ± .05	141
35	Bonny Best, Livingston	.31	.20	.25 ± .04	141
26	Scarlet Dawn, Comstock-Ferre	.33	.21	.25 ± .04	141
59	Burpee's Globe, Burpee	.27	.23	.25 ± .04	141
57	Globe, Eastern States	.34	.20	.24 ± .04	136
13	Michigan State Forcing, Ferry-Morse	.29	.20	.24 ± .04	136
82	Red Cherry, Comstock-Ferre	.27	.22	.24 ± .01	136
65A	Marglobe, Certified, Landreth	.28	.20	.24 ± .03	136
51A	Bloomsdale, Landreth	.31	.18	.24 ± .04	136
55	Grothen's Globe, Ferry-Morse	.33	.16	.23 ± .05	130
55A	Grothen's Red Globe (Certified) Landreth	.29	.15	.23 ± .05	130
62	Marglobe, F. H. Woodruff	.28	.20	.23 ± .03	130
23	Avon Early, Burrell	.32	.19	.23 ± .04	130
52	Beauty, Livingston	.24	.22	.23 ± .01	130
54	Break O'Day, Certified, F. H. Woodruff	.28	.20	.23 ± .03	130
78	Pritchard, Eastern States	.27	.20	.23 ± .03	130
68	Rutgers, Burpee	.30	.17	.22 ± .05	124
69A	Rutgers (Certified) Landreth	.28	.19	.22 ± .04	124
74	Italian Pink Plum, Perry	.30	.15	.22 ± .05	124
60	Master Marglobe, Stokes	.24	.20	.22 ± .01	124
20	Penn. State Earliana, Eastern States	.26	.17	.22 ± .03	124
72	N. Y. State, Hart and Vick	.30	.17	.21 ± .04	119
14	Canadian, Harris	.24	.17	.21 ± .03	119
77A	Penn. State, Landreth	.26	.15	.18 ± .04	102
80	Pritchard, Stokes	.18	.09	.13 ± .03	74

*Standard Deviation from the mean.

Table 5 is a recapitulation of a part of the data in Table 4. Here the strains of each important variety are grouped for comparison. The data show some similarity between strains of each variety, but the variations are not perfectly correlated with only one season's samples.

Grouping the strains of the varieties aids in evaluating them as carriers of ascorbic acid. The nine Massachusetts Field Station strains are consistently

Table 5.—Ascorbic Acid Content of Different Strains of the Same Variety of Tomato (1936 Crop)

Plot	Variety and Strains	Ascorbic Acid Milligrams per Gram			Equivalent International Units per Ounce
		Maximum	Minimum	Mean and S. D.*	
6E	Greenhouse No. 9-1936	.50	.41	.44 ± .03	249
6	Mass. Field Station, No. 7-1	.58	.29	.41 ± .09	232
5	Mass. Field Station, No. 2-1	.50	.30	.39 ± .08	221
6B	Mass. Field Station, No. 11-1	.54	.31	.39 ± .07	221
6A	Mass. Field Station, No. 8-1	.49	.29	.37 ± .05	209
6C	Mass. Field Station, No. 13-1	.43	.28	.36 ± .05	204
4	Mass. Field Station x Market Garden Field Station	.58	.24	.35 ± .11	198
6D	Mass. Field Station, No. 15-1	.35	.27	.31 ± .03	175
6F	Mass. Field Station x Baltimore, No. 11-Fall 1935	.43	.18	.30 ± .09	170
	Average all Field Station strains	—	—	.37 ± .08	209
3	Comet, Perry	.37	.33	.35 ± .02	198
1	Comet, Forbes	.39	.30	.33 ± .04	187
2	Comet, Grey	.38	.22	.29 ± .05	164
	Average all Comet Strains	—	—	.32 ± .04	181
29	John Baer, Ferry-Morse	.48	.29	.35 ± .06	198
28	John Baer, Eastern States	.37	.19	.28 ± .06	158
30	John Baer, Harris	.29	.26	.27 ± .01	153
	Average all John Baer strains	—	—	.31 ± .06	175
47	Stone (Certified), F. H. Woodruff	.40	.21	.31 ± .06	175
46	Stone, Livingston	.46	.22	.30 ± .08	170
44	Stone, Burpee	.40	.23	.29 ± .06	164
45	Stone, Eastern States	.28	.23	.26 ± .02	147
	Average all Stone strains	—	—	.29 ± .06	164
37	Bonny Best, F. H. Woodruff	.50	.23	.34 ± .08	192
31	Special Bonny Best, Burrell	.38	.23	.31 ± .06	175
32	Reselected Bonny Best, Comstock-Ferre	.36	.27	.30 ± .04	170
34	Bonny Best, Harris	.32	.22	.29 ± .03	164
33	Bonny Best, Ferry-Morse	.36	.21	.29 ± .05	164
38	Super Standard Bonny Best, Stokes	.33	.19	.25 ± .06	141
36	Bonny Best, Shirley	.29	.23	.25 ± .03	141
35	Bonny Best, Livingston	.31	.20	.25 ± .04	141
	Average all Bonny Best strains	—	—	.29 ± .05	164
61	Master Marglobe, F. H. Woodruff	.37	.27	.31 ± .03	175
62A	Marglobe, Abbott and Cobb	.38	.24	.31 ± .03	175
66	Marglobe, Livingston	.39	.22	.30 ± .05	170
65	Marglobe, Forbes	.36	.22	.28 ± .04	158
63	Marglobe, Burpee	.30	.19	.26 ± .05	147
64	Marglobe, Eastern States	.30	.21	.25 ± .03	141
65A	Marglobe (Certified), Landreth	.28	.20	.24 ± .03	136
62	Marglobe, F. H. Woodruff	.28	.20	.23 ± .03	130
60	Master Marglobe, Stokes	.24	.20	.22 ± .01	124
	Average all Marglobe strains	—	—	.27 ± .04	153
58	Globe, Livingston	.36	.17	.27 ± .09	153
59	Burpee's Globe, Burpee	.27	.23	.25 ± .04	141
57	Globe, Eastern States	.34	.20	.24 ± .04	136
	Average all Globe strains	—	—	.26 ± .05	147
69	Rutgers, Forbes	.37	.24	.29 ± .04	164
71	Rutgers, Stokes	.37	.18	.26 ± .07	147
70	Rutgers, Perry	.38	.19	.25 ± .06	141
68	Rutgers, Burpee	.30	.17	.22 ± .05	124
69A	Rutgers, (Certified), Landreth	.28	.19	.22 ± .04	124
	Average all Rutgers strains	—	—	.25 ± .05	141
79	Pritchard, Livingston	.41	.19	.27 ± .07	153
78	Pritchard, Eastern States	.27	.20	.23 ± .03	130
80	Pritchard, Stokes	.18	.09	.13 ± .03	74
	Average all Pritchard strains	—	—	.21 ± .08	119

*Standard Deviation from the mean.

high, averaging 207 units per ounce. It appears possible that by selection and breeding, strains of tomatoes high in ascorbic acid can be obtained. Undoubtedly, it is more than a coincidence that all three of the Comet strains, seeds of which were grown in different parts of the United States, show a high value. Canners of tomatoes and tomato juice may be able to select and perfect improved strains of tomatoes of higher ascorbic acid potency than are now grown commercially.

The study of the effect of variety and strain on the ascorbic acid content of tomatoes was continued in 1937. The tomatoes were grown on the same soil plots and with the same fertilizer treatment as in the previous year. The 28 varieties and strains tested had a lower range of ascorbic acid than in 1936 as is shown in Table 6. On grouping the tomatoes genetically, the Comet strains again showed a high ascorbic acid content. The Massachusetts Field Station strains were considerably less potent than in 1936. Bonny Best and Marglobe strains were in the same relationship to each other; but, as in the other cases, were lower in ascorbic acid content.

TABLE 6.—ASCORBIC ACID CONTENT OF 28 VARIETIES AND STRAINS OF TOMATOES (1937 CROP)

Plot	Variety and Strain	Ascorbic Acid Milligrams per Gram			Equivalent International Units per Ounce
		Maximum	Minimum	Mean and S. D.*	
9	Comet, Eastern States	.46	.27	.34 ± .07	192
11	Comet, Harris	.39	.26	.32 ± .05	181
12	Comet, Perry	.35	.26	.30 ± .03	170
10	Comet, Hart and Vick	.35	.26	.30 ± .03	170
	Average all Comet strains	—	—	.31 ± .04	178
5	Mass. Field Station, No. 13-1	.35	.23	.30 ± .04	170
3	Mass. Field Station, No. 5	.34	.19	.30 ± .05	170
4	Mass. Field Station, No. 8-1	.39	.24	.30 ± .06	170
6	Mass. Field Station, No. 15-1	.35	.24	.30 ± .04	170
2	Mass. Field Station, No. 2-1	.31	.24	.28 ± .03	158
7	Mass. Field Station, No. 18-1	.33	.19	.26 ± .05	147
8	Mass. Field Station, No. 19	.33	.17	.23 ± .05	130
	Average all Field Station strains	—	—	.28 ± .05	159
30	Bonny Best, Will	.36	.25	.30 ± .04	170
26	Bonny Best, Landreth	.33	.20	.26 ± .04	147
27	Bonny Best, Ross Brothers	.34	.19	.25 ± .04	141
28	Bonny Best, Stokes	.31	.17	.24 ± .05	136
29	Bonny Best (special strain)	.27	.18	.23 ± .03	130
25	Bonny Best, Livingston	.26	.19	.23 ± .03	130
	Average all Bonny Best strains	—	—	.25 ± .04	142
48	Marglobe, Harris	.33	.22	.26 ± .03	147
47	Marglobe, Eastern States	.29	.25	.26 ± .01	147
49	Marglobe, Landreth	.28	.18	.22 ± .04	124
50	Marglobe, Livingston	.28	.18	.22 ± .03	124
	Average all Marglobe strains	—	—	.24 ± .03	135
31	John Baer, Harris	.34	.16	.26 ± .06	147
19	Earliana, Harris	.29	.19	.25 ± .03	141
20	Earliana, Livingston	.27	.18	.25 ± .03	141
58	Stone, Livingston	.36	.20	.25 ± .06	141
51	Globe, Livingston	.27	.20	.25 ± .03	141
53	Rutgers, Landreth	.28	.17	.22 ± .04	124
54	Rutgers, Stokes	.27	.15	.20 ± .04	113

*Standard Deviation from the mean.

The 1938 crop of tomatoes was also examined for ascorbic acid. The 22 varieties and strains as seen in Table 7 had a higher range of ascorbic acid than in 1937 but results are comparable to those of 1936. On grouping the tomatoes genetically the Massachusetts Field Station strains were found to be considerably richer in ascorbic acid content than in 1937. Stone, Marglobe and Rutgers strains were in the same relationship to each other, but, as in the other cases, were higher in ascorbic acid content than those of 1937 and were comparable to those of 1936.

Table 7.—Ascorbic Acid Content of 22 Varieties and Strains of Tomatoes (1938 Crop)

Plot	Variety and Strain	Ascorbic Acid Milligrams per Gram			Equivalent International Units per Ounce
		Maximum	Minimum	Mean and S. D.*	
1C	Mass. Field Station, 1937-20	.49	.36	.43 ± .05	243
1E	1937-24M. F. S. x Baltimore, F 4	.44	.37	.43 ± .06	243
1	Waltham Forcing, M. F. S.	.57	.30	.42 ± .09	238
1D	Mass. Field Station, 1937-18	.59	.28	.40 ± .10	226
1B	Mass. Field Station, 1937-16	.41	.26	.33 ± .06	187
1A	Mass. Field Station, 1937-19	.46	.24	.33 ± .07	187
	Average all Field Station strains	—	—	.39 ± .07	221
37	Stone, Eastern States	.38	.23	.31 ± .06	175
36	Stone, Livingston	.38	.20	.30 ± .04	170
	Average all Stone strains	—	—	.30 ± .05	170
43	Master Marglobe, Stokes	.40	.28	.33 ± .05	187
42	Master Marglobe, F. H. Woodruff	.37	.18	.30 ± .06	170
46	Marglobe, Eastern States	.35	.20	.28 ± .05	158
47	Marglobe, Landreth	.32	.17	.23 ± .05	130
	Average all Marglobe strains	—	—	.28 ± .05	158
49	Rutgers, Stokes	.34	.22	.27 ± .04	153
48	Rutgers, Landreth	.41	.19	.24 ± .04	136
	Average all Rutgers strains	—	—	.25 ± .04	141
13	Lister's Protection, Grey	.53	.33	.44 ± .07	249
2	Comet, Grey	.52	.34	.42 ± .07	238
4	Mich. State Forcing, Grand Rapids	.46	.30	.38 ± .07	215
55	Globe, Livingston	.45	.24	.35 ± .08	198
32	Scarlet Dawn, Comstock-Ferre	.42	.25	.34 ± .05	192
6	Grand Rapids Forcing, Grand Rapids	.38	.29	.33 ± .03	187
40	Greater Baltimore, F. H. Woodruff	.35	.25	.29 ± .03	164
27	Bonny Best, Henderson	.33	.18	.28 ± .04	158

*Standard Deviation from the mean.

Table 8 compares the identical strains and varieties of the 1936, 1937, and 1938 growing seasons. Although many factors influence growth, three years of experimental evidence tend to show that the ascorbic acid potency in tomatoes may be an inherited characteristic.

TABLE 8.—ASCORBIC ACID CONTENT OF IDENTICAL STRAIN TOMATOES FOR THREE SUCCESSIVE YEARS

Variety and Strain	1936		1937		1938	
	Ascorbic Mg. per Gram*	Acid I. U. per Ounce	Ascorbic Mg. per Gram*	Acid I. U. per Ounce	Ascorbic Mg. per Gram*	Acid I. U. per Ounce
Mass. Field Station, No. 2-1	.39 ± .08	221	.28 ± .04	158		
Mass. Field Station, No. 8-1	.37 ± .05	209	.30 ± .06	170		
Mass. Field Station, No. 13-1	.36 ± .05	204	.30 ± .04	170		
Mass. Field Station, No. 15-1	.31 ± .03	175	.30 ± .04	170		
Mass. Field Station, No. 18-1			.26 ± .05	147	.40 ± .10	226
Mass. Field Station, No. 19			.23 ± .05	130	.33 ± .07	187
Comet, Perry	.35 ± .02	198	.30 ± .03	170		
Comet, Grey	.29 ± .05	164			.42 ± .07	238
Stone, Livingston	.30 ± .08	170	.25 ± .06	141	.30 ± .04	170
Stone, Eastern States	.26 ± .02	147			.31 ± .06	175
Marglobe, Livingston	.30 ± .05	170	.22 ± .03	124		
Marglobe, Eastern States	.25 ± .03	141	.26 ± .01	147	.28 ± .05	158
Marglobe, Landreth	.24 ± .03	136	.22 ± .04	124	.23 ± .05	130
Master Marglobe, F. H. Woodruff	.31 ± .03	175			.30 ± .06	170
Master Marglobe, Stokes	.22 ± .01	124			.33 ± .05	187
Rutgers, Stokes	.26 ± .01	147	.20 ± .04	113	.27 ± .04	153
Rutgers, Landreth	.22 ± .04	124	.22 ± .04	124	.24 ± .04	136
Globe, Livingston	.27 ± .09	153	.25 ± .03	141	.35 ± .08	198
John Baer, Harris	.27 ± .01	153	.26 ± .06	147		
Bonny Best, Livingston	.25 ± .04	141	.23 ± .03	130		
Greater Baltimore, F. H. Woodruff	.30 ± .04	170			.29 ± .03	164
Lister's Protection, Grey	.29 ± .07	164			.44 ± .07	249
Mich. State Forcing, Grand Rapids	.26 ± .07	147			.38 ± .07	215
Scarlet Dawn, Comstock-Ferre	.25 ± .04	141			.34 ± .05	192
Grand Rapids Forcing, Grand Rapids	.25 ± .05	141			.33 ± .03	187

*Mean and Standard Deviaticn from the mean.

Effect of Nitrogenous Fertilizers

Twelve strains of the Comet variety were grown in beds and on benches in a greenhouse. The fertilizer for the beds was high in nitrogen and the benches contained nitrogen only sufficient for growth. The ascorbic acid content was found to vary considerably between strains. The 12 strains grown in the beds (high nitrogen) ranged from 74 to 114 units per ounce of tomato; those grown on the benches (low nitrogen) ranged from 96 to 136 units. In each strain, the tomatoes grown on the benches contained more ascorbic acid than those grown in the beds. The short, bushy growth of the plants on the benches (low nitrogen) contrasted markedly with the tall growth in the beds. "Sightmeter" obervations showed that the light intensity throughout the day was higher on the beds. The influence of sunlight on the ascorbic acid content of growing materials has not been determined; moreover, moisture content of the soil may vary with sunlight intensity. Because of this variation in sunlight, no definite relationship between nitrogen and the ascorbic acid content of tomatoes can be determined from this experiment.

Distribution of Ascorbic Acid in the Tomato

Ascorbic acid in apples has been found by Fellers, Cleveland, and Clague (1933) to be concentrated in or near the skin, with a small amount located in other sections. Hothouse tomatoes of the Comet variety were used in determining the location of ascorbic acid. The locule section of the tomato, containing the seeds and gelatinous material, had the largest amount of ascorbic acid, 0.19 mg. per gram (Table 9); the outside skin and flesh, 0.11 mg. per gram; and the center core, 0.11 mg. per gram. Although the locule section has the largest amount of ascorbic acid per unit of weight, its volume in relation to the remainder of the fruit is small. For this reason, as shown in Table 9, the total ascorbic acid in the locule section is considerably less than that in the outside skin and flesh.

TABLE 9.—ASCORBIC ACID CONTENT OF VARIOUS SECTIONS OF THE TOMATO (COMET VARIETY)

Sample	Number of Determinations	Ascorbic Acid Milligrams per Gram			Ascorbic Acid Total Milligrams		
		Outside Flesh and Skin	Seeds and Liquid in Locules	Center Core	Outside Flesh and Skin	Seeds and Liquid in Locules	Center Core
1	6	.07	.15	.11	.16	.07	.10
2	6	.10	.20	.10	.22	.15	.09
3	6	.12	.28	.08	.26	.19	.06
4	6	.15	.23	.15	.31	.12	.11
5	6	.10	.12	.12	.30	.14	.08
Average		.11	.19	.11	.25	.14	.09

The outside flesh and skin constitute approximately 60 percent by weight; the seeds and liquid in locules, approximately 18 percent; and the center core, approximately 22 percent.

Effect of Size

McHenry and Graham (1935) found an inverse relationship between size and ascorbic acid content of tomatoes. However, in the common commercial varieties and strains of tomatoes grown in 1936, no correlation could be found between size and ascorbic acid content. The largest and the smallest tomato fruit of each variety and strain were compared. In 48 cases the largest tomato had a greater amount of ascorbic acid per gram of tomato than the smallest one, the average percentage difference being 40.3. In the remaining 43 cases the smallest tomato had the greater amount of ascorbic acid per unit of weight, the average percentage difference being 18.9.

Effect of Maturity

Although all tomatoes selected for the determination of ascorbic acid in tomato varieties were harvested when considered to be fully ripe, there was difficulty in estimating the same degree of ripeness for each selection. To ascertain whether the stage of maturity influenced the amount of ascorbic acid in the varieties determined, six varieties, fully grown, were examined when green and hard, when half-ripe, and when fully ripe. The results are shown in Table 10. Fruits at the different stages of development were picked from the same plants.

Six to eight tomatoes were selected, typical of the degree of maturity to be tested. Three composite samples of from 15 to 20 grams, were used. The data show no consistent increase in the ascorbic acid content of tomatoes during the three stages of maturity studied and, therefore, it cannot be considered that the degree of ripeness influenced the variation in ascorbic acid content among tomato strains and varieties shown in Tables, 4, 5, 6, 7, and 8.

TABLE 10.—EFFECT OF STAGE OF MATURITY ON ASCORBIC ACID CONTENT OF TOMATOES

	Hard Green		Half Ripe		Fully Ripe	
	Ascorbic Acid Mg. per Gram	I. U. per Ounce	Ascorbic Acid Mg. per Gram	I. U. per Ounce	Ascorbic Acid Mg. per Gram	I. U. per Ounce
John Baer, Harris						
1	.28		.31		.29	
2	.17		.18		.26	
3	.28		.35		.26	
Average	.23	130	.28	158	.27	153
Beauty, Livingston						
1	.25		.35		.22	
2	.16		.29		.22	
3	.24		.22		.24	
Average	.22	124	.29	164	.23	130
Stone, Burpee						
1	.32		.27		.25	
2	.38		.25		.40	
3	.27		.26		.24	
Average	.32	181	.26	146	.29	164
Clark's Early, F. H. Woodruff						
1	.19		.26		.30	
2	.22		.21		.21	
3	.24		.31		.27	
Average	.22	124	.26	147	.26	147
Success, Harris						
1	.36		.26		.29	
2	.26		.21		.21	
3	.37		.31		.28	
Average	.33	187	.26	147	.26	147
Comet, Perry						
1	.27		.45		.37	
2	.39		.30		.33	
3	.33		.41		.35	
Average	.33	187	.39	221	.35	198

Effect of Storage

The samples of tomato varieties and strains in Tables 4, 5, 6, 7, and 8, were titrated for ascorbic acid as soon as possible after the fruit had been harvested. No samples were stored overnight. However, to determine the effect of storage at room temperature on the ascorbic acid content of fully ripe tomatoes, an experiment using two varieties was arranged. The results given in Table 11 show that up to 240 hours of storage (10 days) there was no apparent loss in ascorbic acid. Hence, ripe tomatoes may be stored with little loss for several days or even weeks after harvesting.

Green Marglobe tomatoes shipped from Florida in January were partly colored upon arrival in Amherst. Some were wrapped in parchment wraps. Examination for ascorbic acid showed that wrapped and unwrapped, fully and partly ripe fruit had essentially the same content, 91 to 97 units per ounce. This value is considerably less than was found in northern-grown Marglobes.

TABLE 11.—EFFECT OF LENGTH OF STORAGE OF FULLY RIPE TOMATOES AT ROOM TEMPERATURE ON ASCORBIC ACID CONTENT

Variety and Hours of Storage	Ascorbic Acid, Milligrams per Gram					Equivalent International Units per Ounce
	Sample 1	Sample 2	Sample 3	Sample 4	Average	
Marglobe:						
Fresh	.29	.27	.24	.30	.27	153
20	.25	.24	.16	.28	.23	130
44	.38	.30	—	—	.34	192
68	.24	.26	.28	.20	.25	141
92	.35	.31	.24	.41	.33	187
140	.22	.27	.22	.20	.23	130
190	.32	.21	.28	.20	.25	141
240	.19	.28	.22	.32	.25	141
Greenhouse, No. 9-1936:						
2	.42	.41	.42	.50	.44	249
48	.45	.34	.30	.37	.37	209
96	.38	.38	.38	.52	.42	238
168	.33	.36	.30	.36	.34	192
216	.40	.30	.25	.51	.37	209

TABLE 12.—EFFECT OF CANNING ON ASCORBIC ACID CONTENT OF TOMATO JUICE

Sample No.	Description of Sample and Process	Ascorbic Acid	
		Mg. per Gram	I. U. per Ounce
1	Raw tomatoes	.19	108
2	Juice after pulping the cooked tomatoes (total solids 5.386 percent, acid mixture added immediately to prevent loss of ascorbic acid), average of 2 samples	.18	102
	Canned in Tin Cans		
3	Juice brought to boiling, filled into cans, sealed, processed at 100° C. for 10 minutes, cooled in running water to 43° C., opened immediately and acid added	.20	113
4	Same juice as 3, stored 43 days at 21° C	.20	113
5	Juice concentrated to 9.288 percent total solids in open kettle, subsequent treatment same as for juice 3	.15	85
	Canned in Glass Jars		
6	Juice brought to boiling, sealed, processed at 100° C. for 10 minutes, opened, acid mixture added, cooled to 52° C	.18	102
7	Juice processed at 100° C. for 10 minutes, cooled in jar to 43° C. (approximately 2 hours)	.19	108
8	Same juice as 7, after 1 hour	.19	108
9	Same juice as 7, after 3 hours	.19	108
10	Same juice as 7, after 5 hours	.19	108
11	Same juice as 7, after 12 hours	.19	108
12	Same juice as 7, after 24 hours	.19	108
13	Same juice as 7, after 14 days	.19	108
14	Same juice as 7, after 30 days	.17	96

STUDY OF ASCORBIC ACID IN CANNED TOMATO JUICE

Effect of Canning

Marglobe tomatoes were quartered, heated in a steam-jacketed kettle to soften, and then forced through a fine iron screen to remove the pulp. The description of the canning process and sampling for ascorbic acid is given in Table 12.

The loss of ascorbic acid during the heating and pulping processes was insignificant. The greatest destruction occurred during the concentration of the pulped juice. Concentration of home-manufactured juice is advisable as it removes some of the excess water thereby preventing separation of finely divided particles. Commercially canned tomato juice is homogenized to obtain a uniform suspension and therefore concentration is unnecessary. No noticeable destruction of ascorbic acid occurred when glass and tin containers were filled with juice, sterilized, and cooled. This table shows the general trend of ascorbic acid destruction during the manufacture of tomato juice.

Effect of Storage of Canned Juice

Ascorbic Acid Studies

The data in Table 12 show that there was no apparent loss in ascorbic acid during a 30-day storage period. No appreciable loss during a storage period of 121 days is also shown by the data in Table 2.

Daniel and Rutherford (1936) stored tomato juice in glass jars and jars wrapped in black photographic paper for six months (209 days). The juice stored in wrapped jars lost 34 percent of its ascorbic acid and the unwrapped jars 24 percent. As this evidence was not in agreement with other storage data, it seemed advisable to conduct an experiment for a period of over 121 days.

Tomato juice containing 67 international units of ascorbic acid per ounce was stored in plain and amber glass containers under dark and normal light conditions. Table 13 shows that there was a small continuous loss of ascorbic acid in plain glass containers whether stored in the dark or in light. Amber glass inhibited losses up to a period of at least 80 days. Storage conditions of light and dark at room temperature (21° C.) did not affect the losses of ascorbic acid in tomato juice. The losses that occurred over a storage period of 400 days did not exceed 25 percent, i. e., from 67 international units per ounce to 50 units. The

TABLE 13.—EFFECT OF STORAGE ON THE ASCORBIC ACID CONTENT OF CANNED TOMATO JUICE

Container and Storage Conditions	Percentage Loss in Ascorbic Acid after Storage for—				
	30 Days	80 Days	165 Days	212 Days	400 Days
Flint glass at room temperature					
Light	5.0	7.2	23.8	20.4	25
Dark	—	4.0	18.6	17.9	19
Amber glass at room temperature					
Light	0	0	15.4	13.8	18
Dark	0	0	20.0	15.3	16
Tin can at room temperature	0	3.2	13.0	17.1	15

storage tests are being continued. These data are not significantly different from those of Daniel and Rutherford (1936) except in the effect of darkness on ascorbic acid. Their storage in the dark, using containers wrapped in black photographic paper, was detrimental to the potency of the tomato juice.

Carotene (Vitamin A) Studies

Paralleling the ascorbic acid storage experiments, carotene determinations were made on samples stored up to 400 days at room temperature and in diffused light. The carotene was determined by the method of Russell, Taylor, and Chichester (1935) as modified by DeFelice and Fellers (1938). The well-mixed contents of three containers were used for analysis.

In general, the loss of carotene in glass-packed tomato juice during storage was relatively small. From an original content of 20 international units per gram, tomato juice packed in amber glass containers lost 10 percent in 400 days and that in flint glass lost 19 percent in the same period.

Apparently, light has a deleterious influence on the retention of carotene in tomato juice packed in glass bottles. However, ordinary storage periods of a few months should not seriously affect the carotene in the canned or bottled juice.

Variation in Commercial Brands

Nineteen brands of commercially canned tomato juice, from the crop of 1935, were tested for ascorbic acid. Results are presented in Table 14, and varied from 40 international units per ounce to 100 units. The determination for ascorbic acid was made on one sample of each brand. In order to determine the variation within a brand, it was necessary to make a more detailed study.

TABLE 14.—ASCORBIC ACID CONTENT OF 18 COMMERCIAL BRANDS OF CANNED TOMATO JUICE

Brand	Ascorbic Acid		Brand	Ascorbic Acid	
	Mg. per Cc.	I. U. per Ounce		Mg. per Cc.	I. U. per Ounce
1	.18	100	11	.10	57
2	.17	96	12	.09	51
3	.14	78	13	.08	45
4	.13	74	14	.08	45
5	.13	74	15	.07	40
6	.12	68	16	.07	40
7	.12	68	17	.07	40
8	.12	68	18	.07	40
9	.11	62			
10	.10	57	Average	.11	62

Variation in Samples of Same Brand

A sample of the 1935 pack of a commercial brand of tomato juice was purchased in each of 14 retail grocery stores, 6 in Amherst and 8 in Northampton. All samples were packed in tin cans of the same size. The samples varied from

28 international units per ounce to 85 units (Table 15). Five samples of tomato juice packed in 1936 were purchased in Amherst. The samples tested, as shown in Table 15, varied from 51 to 80 units per ounce. The conclusion may be drawn from these data that testing one can of a brand of tomato juice may not give a representative indication of the ascorbic acid content of that brand.

TABLE 15.—ASCORBIC ACID VARIATION IN DIFFERENT SAMPLES OF THE SAME COMMERCIAL BRAND OF CANNED TOMATO JUICE

Place and Year	Store	Ascorbic Acid Mg. per Cc.	Ascorbic Acid I. U. per Ounce
Amherst, Mass., 1935	1	.15	85
	2	.14	80
	3	.13	74
	4	.12	68
	5	.11	62
	6	.08	45
Northampton, Mass., 1935	1	.12	68
	2	.12	68
	3	.10	57
	4	.10	57
	5	.10	57
	6	.10	57
	7	.07	40
	8	.05	28
Average, 1935 pack		.11	61
Amherst, Mass., 1936	1	.14	80
	2	.13	74
	3	.13	74
	4	.12	68
	5	.09	51
Average, 1936 pack		.12	69

Effect of Exposure

Opened tin cans of tomato juice were stored at 5° and 21° C. for a period of 44 hours. Some of the stored juices were protected from the interchange of air by sealing the openings with paraffin. Results are presented in Table 16. The slight difference in the ascorbic acid content of the paraffined and exposed samples does not warrant sealing of opened containers.

It should also be noted that room storage (21° C.) was more detrimental to these samples than cold storage. Storage at 5° C., the average household refrigerator temperature, for periods of 20 hours or more resulted in a 10 to 15 percent loss of ascorbic acid.

TABLE 16.—EFFECT OF EXPOSURE ON THE ASCORBIC ACID CONTENT OF CANNED TOMATO JUICE

Storage Period Hours	Ascorbic Acid, Milligrams per Cc. — Cold Storage (5° C.) Exposed	Cold Storage (5° C.) Paraffined	Room Storage (21° C.) Exposed	Room Storage (21° C.) Paraffined
0	.09	.08	.10	.14
20	.08	.07	.08	.09
44	.08	.07	.07	.08

DISCUSSION OF RESULTS

The chemical determination of ascorbic acid in tomato juice by the 2, 6-dichlorophenolindophenol method was found to check closely the bioassay method of Sherman, La Mer, and Campbell (1922). This is in agreement with the results of Hanning (1936) on tomatoes and with King's (1936) conclusion from a review of the literature. The modified iodine method of Lorenz, Reynolds, and Stevens (1934) gave consistently higher results (factor 0.7) than the guinea pig assay for ascorbic acid.

No reversibly oxidized (dehydro) ascorbic acid was found in tomato juice when reduced by hydrogen sulfide. Hauck (1938) found a small amount present in tomato juice but the quantity indicated is of doubtful significance. McHenry and Graham (1935) reported 0.15 mg. ascorbic acid per gram of tomato tissue both before and after reduction.

The enzymic oxidase for ascorbic acid suggested by Tauber and Kleiner (1935) for the measurement of interfering substances in the titration was not found to be quantitatively specific. These results are in agreement with those of Stotz, Harrier, and King (1937).

The oxidation of ascorbic acid may be catalyzed by copper (Barron, De Meio, and Klemperer, 1936 and Kellie and Zilva, 1935) and by other metals (Mawson, 1935); but iron and tin salts did not interfere with the titration procedure used in these studies. Consequently, ascorbic acid is determined as specifically in tinned tomato juice as in fresh samples by this chemical method.

The probable error in determining the end point of the chemical titration for ascorbic acid was found to be ±2 percent. The difficulty in obtaining uniform samples even from the same batch is well represented in Table 2 where there is a variation of approximately ±10 percent in titrated values. Because of this variation in supposedly identical samples, it is inadvisable to draw definite conclusions from results within a 10 percent range.

Two extractions for ascorbic acid in plant tissue have been shown to be necessary in approximating the true antiscorbutic activity. In routine examinations, however, one extraction is sufficient and the second extraction can be compensated for by the addition of 10 percent of the value for tomato flesh or 16 percent for tomato juice.

Ninety-eight distinct varieties or strains of tomatoes were grown under constant field conditions in 1936 and compared as to ascorbic acid content. The tomato showed considerable variation, with values ranging from a maximum of 249 international units per ounce to a minimum of 74 units. Krauss, Washburn, and Hoffman (1937, 1938), Hoffman[8], and Tripp, Satterfield, and Holmes (1937) reported a considerable variation in tomato strains and varieties. Tripp and his associates in 1936 found the Pritchard variety of tomato grown in Tennessee to have the highest ascorbic acid content of all the varieties tested. In the same year and on similar soil types, but grown in Massachusetts, this variety was shown to be the least potent source of ascorbic acid. This variation seems to be due to many influencing factors but can be attributed to no definite one of the conditions so far studied. A continued study of varieties and strains in 1937 and 1938 showed some correlation between varieties and ascorbic acid content. By selection, it may be possible to increase considerably the ascorbic acid content of the tomato crop. The ascorbic acid content in the tomatoes grown in 1937 was found to be lower than in the tomatoes produced in 1936. The 1938 crop was comparable to 1936. Cultural practices were identical in all three years so the variation is presumably the result of the many influencing factors of the weather during the growing season. Husseman (1937) in 1936 found little ascorbic acid in Wisconsin tomatoes but presents no data.

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[8] Hoffman, I. C., 1937. Personal communication.

No correlation was found between size of a tomato and its ascorbic acid content. These results are not in agreement with those of McHenry and Graham (1935). These authors explained the difference in ascorbic acid content of diploid and tetraploid number tomatoes as the result of fruit size.

The ascorbic acid concentration was consistently higher in the locule section of the one variety tested than in any other part of the fruit. However, the outside flesh and skin contributed the greatest quantity of ascorbic acid to the tomato as a whole. Krauss, Washburn, and Hoffman (1937, 1938), and Hoffman [9] reported that varieties differed in their quantitative distribution of ascorbic acid.

Six varieties showed no significant increase in ascorbic acid content during the ripening process from the hard green stage to the hard ripe stage. Clow and Marlatt (1930), House, Nelson, and Haber (1929), Krauss, Washburn, and Hoffman, (1937, 1938), and Hoffman[9] found a close correlation between the stage of maturity and the ascorbic acid potency.

Parchment wrappers evidently do not influence the ascorbic acid content of shipped tomatoes. Storage of ripe tomatoes of two varieties for 240 hours at room temperature caused no apparent loss of ascorbic acid. No definite data have been reported previously on this subject of storage of fresh, ripe tomatoes.

The manufacture and canning of tomato juice was found to be destructive to ascorbic acid only in a step of the procedure not common to commercial practice, concentration of the pulped juice. Homogenization, a process often used in the commercial manufacture of tomato juice, was found by Barnby and Eddy (1932) and Fellers et al. (1935) to cause no destruction of ascorbic acid. Theoretically, then, commercially canned tomato juice should be as antiscorbutically active as the tomatoes from which it was extracted. Actually, the large quantities prepared commercially necessitate a slow canning process, which results in destruction of ascorbic acid from prolonged contact with the air. The problem of increasing the ascorbic acid content of commercial tomato juice may lie in the direction of a tomato breeding program rather than in a revamping of the canning procedure.

Considerable variation was found in the ascorbic acid content of commercial brands of tomato juice. These results are in agreement with those of Fellers, Clague, and Isham (1935) and Connecticut Experiment Station Food Products Reports (Bailey, 1937, 1938). Variations in samples of the same brand again indicate that representative samples are difficult to obtain.

Storage of tomato juice in three types of containers for 400 days at room temperature resulted in a loss of not more than 25 percent of its ascorbic acid content. The data do not indicate significant differences between storage in tin or glass containers. Daniel and Rutherford (1936) and Hauck (1938) found less loss on storage of tomato juice in tin cans than in glass containers. Hauck showed that storage in glass containers under light or dark conditions resulted in no variation of ascorbic acid content, thereby agreeing with the data in Table 13. Daniel and Rutherford, however, found storage in containers wrapped in black photographic paper to be detrimental.

Opened containers of tomato juice were stored at cold and at room temperatures. More destruction occurred at room temperature than at 5° C. Hauck confirmed the 10 to 15 percent loss of ascorbic acid found after 44 hours storage at refrigerator temperature.

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[9] Hoffman, I. C., 1937. Personal communication.

SUMMARY

1. A four-year investigation was conducted on methods for the determination of ascorbic acid in tomatoes and tomato products. Sampling methods, reagents and technic were studied in adapting the chemical methods to the problem of evaluating the tomato as an antiscorbutic. Effect of season, variety, maturity, storage, and other factors influencing the ascorbic acid content of canned and fresh tomato products were studied.

2. The 2, 6-dichlorophenolindophenol titration for ascorbic acid was found to check more closely with the guinea pig bioassay results than did the modified iodine method. Adaptation of the dye technic to tomato studies included a second extraction for ascorbic acid using a mixture of 2 percent metaphosphoric and 3 percent trichloroacetic acid.

3. No oxidized (dehydro) ascorbic acid was found in raw or cooked tomatoes and tomato products.

4. An oxidase enzyme method for differentiating ascorbic acid from other reducing substances did not yield satisfactory results in this tomato study.

5. The chemical titration for ascorbic acid is as specific on canned tomato juice as on fresh samples.

6. The chemical determination of ascorbic acid in tomatoes or tomato products is subject to an error of approximately ±2 percent. Unavoidable variations in sampling increase this to a probable error of at least ±10 percent.

7. Tomato varieties and strains showed considerable range in ascorbic acid content (74 to 249 international units per ounce). The possibility that ascorbic acid content may be an inherited characteristic is indicated by three seasons' study of several strains of many varieties of tomatoes. Tomatoes should exceed 150 international units per ounce to be classed as higher than average in ascorbic acid content.

8. Outside flesh and skin were found to contribute the most ascorbic acid to the whole tomato, but it was in the seeds and gelatinous material of the locule section that this acid was most concentrated. Neither fruit size nor degree of ripeness influenced the ascorbic acid content.

9. The use of parchment wrappers was not detrimental to the ascorbic acid content of tomatoes when they were held for 10 days in cold storage or at room temperature.

10. Concentration of tomato juice to prevent separation of suspended solids destroyed 25 percent of the ascorbic acid originally present. Storage of tomato juice under either dark or light conditions for 400 days caused not more than a 25 percent loss of ascorbic acid. The carotene content of canned or bottled tomato juice was not seriously affected by ordinary storage of a few months.

11. Commercial brands of tomato juice contained 40 to 100 international units of ascorbic acid per ounce, and the variation within one brand was found to be from 28 to 85 units per ounce.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

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Annual Report

For the Fiscal Year Ending November 30, 1938

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION — 1938

INTRODUCTION

F. J. Sievers, Director

Experiment stations, as public service agencies, are organized to contribute to the promotion of the general welfare of the nation. In the past, they have confined themselves very largely, if not entirely, to the research necessary to solve the problems of the farmer. As a result of their efforts it can be shown, quite convincingly, that there have been pronounced advances in the efficiency of agricultural production. This contribution might have proved more adequate if there had been provision for the assimilation of the products of efficiency. Unemployment is a natural product of efficiency and unless it is so recognized and dealt with it readily reaches a stage where it prominently affects public welfare. Industry, irrespective of its concern with problems of public welfare, is not primarily organized to make the solution of these problems its major objective. On the other hand, under our national democratic policy, we are unfamiliar with and resent government interference with business and, as a result, it has been a fond hope that the profit system of industry would, if given free rein, solve unemployment, our major social and economic problem. To the extent that a solution has not been forthcoming there has been an appeal to public service agencies. This attitude, while not entirely new, has become more evident during the last several years than through any other similar period in our history.

Fortunately, in the field of agriculture, the experiment stations through their research programs have, in the course of the last fifty years, fortified themselves with much factual material regarding the progress and future of this industry. To give intelligent leadership to agriculture, an industry so intricately involved in our entire social and economic scheme, is, nevertheless, an assignment that should not be accepted without assurance of comparative freedom from bias or prejudice. In a nation where industry has been practically without restraint in its operations and where extreme competitive activities have had free rein during all time, it requires considerable faith and courage to promote a program that has public welfare and not profit as the first objective. The experiment stations will establish leadership in this service to just the extent that their direction is sound and their research is applicable and dependable. Developments will naturally be slow and no spectacular changes in program or in the nature of results should be anticipated or encouraged.

The major problems confronting present-day society, while not difficult to locate, are so involved in nature that their solution seems an almost insurmountable task without resort to such regulatory measures as are considered generally undesirable. As an illustration, there is produced within the New England states sufficient milk to confront the dairy farmer with difficulty in finding a profitable outlet, while another portion of the population, within the same area, is economically unable to obtain a sufficient supply of this commodity to insure the requirements of good health. It is questionable, however, whether this matter can be properly adjusted without dealing with milk as a public utility. The market gardener suffers because of low prices for his produce, while the urban consumer cannot afford to buy fresh vegetables at the price demanded. Eventually we may become convinced of some of the extravagances of a system that is directed solely by the profit motive, and then agencies which are primarily concerned with general public welfare will gradually assume a greater degree of leadership in providing a solution for these fundamental problems.

During the last year the Lang Fund was increased by an additional $2,000 by Mrs. Henry Lang, the original donor, thus bringing the total support from this source to $12,000. The research made possible by this fund has served to advance our knowledge in human nutrition at a time when there is a distinct need for reliable information in a field where there is so much confused thinking because of the high-powered advertising behind numerous nostrums recommended as curatives for nutritional disorders or deficiencies.

Increases in financial support from Bankhead-Jones (Federal) sources have been available for the last four years but these will terminate with June 30, 1940, after which the Massachusetts Experiment Station will receive a total apportionment of approximately $20,000 annually from this source. It is hoped that this federal support will, in part, serve to promote certain new and much desired services for which adequate state funds have not been available. Such organized groups as the poultrymen, the greenkeepers, and the arborists, all of whom are convinced of the worthiness of their case, are very insistent in their demands for research.

The poultry industry is in real need for authentic information regarding the merits of the numerous and specific claims of manufacturers of poultry feeds. This phase of the subject has reached such prominence that recent findings have forced modifications in the regulatory laws in some states and it is highly desirable that Massachusetts should keep abreast in this field and be ready to make her proportionate contribution to the general demand for a sounder basis for the evaluation of livestock feeds.

The greenkeepers suffered temporary disappointment in failing to gain favorable legislative action on a request for funds adequate to support research in turf management. The need for this service was felt so keenly, however, that their Association made available a small sum of money to initiate research while anticipated legislative action is pending.

The demands of the arborists have been satisfied to a considerable degree through the enlarged facilities for nursery culture studies and it is hoped that the problems of the arborists and nurserymen may be correlated sufficiently to be dealt with under the same research procedure.

The completed Nutrition Laboratory is serving as a real clearing house for the type of departmental cooperation that any sound program in this specialized field requires. The physical plant and its equipment provide the flexibility necessary to encourage several departments to utilize these facilities to their full capacity.

At the Cranberry Station, through special funds provided by the Cape Cod Cranberry Growers' Association, it has been possible to continue work in weed control and also to inaugurate investigations in fruit storage. The increased interest not only in blueberries and strawberries but more recently in beach plums is exerting tremendous pressure for expansion in our activities which will need to be met either through additional financial support or through lesser emphasis on research now under way in other fields.

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

Adjustments in Dairy Farm Organization and Practices in Massachusetts. (C. R. Creek and Malcolm Butler.) This study was initiated in 1937 in cooperation with the Bureau of Agricultural Economics of the United States Department of Agriculture. Survey records were taken of the farm business on 253 dairy farms in 11 counties of Massachusetts for the period May 1936 to April 1937. The wholesale dairy farms were analyzed in five groups: Berkshire County, Connecticut Valley counties, Worcester County, Northeastern counties and Southeastern counties.

Size of business was an important income-producing factor in all areas except Berkshire where size of business was smaller on the more profitable farms. Here feeding efficiency made up for the disparity in herd size. High milk production per cow was important in all areas except Worcester; in this central area, feeding and labor efficiency balanced the lower production per cow. Diversification was necessary to higher incomes in all areas except the Connecticut Valley. Those farms receiving higher milk prices than their neighbors also received higher incomes in Berkshire and the Northeastern counties. These Northeastern dairymen also had to husband their capital more closely than those in other sections to gain larger income.

Records were obtained for 54 dairy farms where milk was sold on retail routes. In general these farms were much larger in size of herd and number of men working than the wholesale farms. They were more specialized in the dairy enterprise and received a much higher price for milk sold. Milk production per cow was also higher.

Labor income on all of these retail farms averaged $3241 with a herd of 24 cows compared to $246 for all wholesale farms with 19 cows each.

Farm business analysis factors and a financial summary of the farm business have been prepared by areas for distribution to the farmers who cooperated in this study by giving records of their farm business. The various factors and items for the individual farm have been entered on the summary so that each dairyman may compare his farm to the high and low profit groups to determine the factors which should be improved. This study is being prepared for publication.

Case studies were made of the farm organization and practices on three farms located in Middlesex and Worcester counties in the Nashoba fruit area

Farm A was primarily a wholesale dairy farm which had a ten-acre orchard as a minor enterprise. It was classed as a farm with an abundance of hayland. Recommendations for this farm were to increase the milking herd by four cows and raise more replacements as one means of utilizing an excess of hay produced. A budget calculated for this change showed an increase in net cash income of $342. The orchard enterprise was supplementary to dairy on this farm and will be maintained at its present size by replacing old trees. A net income of $280 was received from cordwood and the operator received a gross income of $500 from outside work with a truck in 1937.

Farm B was a dairy, poultry, and fruit farm located in the same district as Farm A. This farm was classified as one with scarcity of hayland and a rundown orchard. Low labor income was caused by (1) low productivity of the orchard, (2) high cost of grain and hay for cattle, and (3) inefficient utilization of labor. Definite and extensive recommendations were made for improvement of the orchard enterprise on this farm because it is a potential source of considerable income. A method was outlined whereby hay and grain costs could be reduced, providing a greater net return from the dairy enterprise. The poultry business is supplementary and will be maintained at the present size.

Farm C was called a well-managed farm having large dairy and fruit enterprises which were of equal importance in the farm organization. This farm was the largest of the three in acreage and in total size of the farm business. The dairy enterprise was a purebred Guernsey cattle business, and in 1937 income from cows and calves sold amounted to $1095. The fruit and dairy enterprises are well organized and operated at optimum capacity. No changes are contemplated in either enterprise. Farm C was an excellent example of a dairy-fruit farm which was well managed and showed a high labor income.

Enterprise Relationships and Farm Organization on Selected Farms in Massachusetts. (C. R. Creek and J. E. Donley.) During the summer of 1938 farm records were taken from farm account books and cash records on 114 poultry farms in the seven eastern counties of Massachusetts. On the basis of percentage of receipts these farms were classified into groups of 71 wholesale, 34 retail, and 9 breeding (baby chicks and hatching eggs) farms for detailed analysis.

The breeding farms showed the highest labor income, the largest size of flock, and the highest egg production per bird. Sales of baby chicks and hatching eggs contributed materially to income.

Retail farms received the highest average price per dozen for eggs, but showed the lowest labor income per farm and per bird. Factors which contributed to low incomes on retail farms were (1) small flocks of laying birds, (2) low egg production per bird, (3) inefficiency in the use of labor, and (4) high capital investment per bird housed. Because of lack of diversification, retail farms were more adversely affected than the two other types by the unfavorable feed price — egg price ratio (7.3 dozens were required to purchase 100 pounds of feed) in 1937. The time spent in delivering eggs on retail routes was not available for supervision and management of the farm. This factor apparently was responsible for the smaller average number of layers and for lower egg production.

The wholesale farms were larger than the retail, had higher egg production per bird, and were operated more efficiently. More broilers and baby chicks were sold than on retail farms. Some of the wholesale farms had crop and fruit enterprises which contributed to the farm income. Such enterprises are especially important when the egg—feed price ratio is unfavorable.

In the wholesale classification, the 12 highest income farms were larger in size of flock and number of men working than the 12 lowest income farms. Labor was used more efficiently as shown by 300 more birds per man, higher cash receipts per man, and lower labor cost per bird. Investment per bird was $4.83 less on the high profit farms. Egg production was 185 eggs per bird, which was 38 eggs more than on the low profit farms. On the most profitable farms labor income per bird was $1.83, while the lowest profit group showed a labor loss of $1.03 per bird.

In the retail classification, the lowest income farms were larger in size of business than the highest income group. However, egg production was lower, labor was used less efficiently, and the investment in the farm was not used to capacity. The average price per dozen received for eggs was 3.5 cents higher on the most profitable retail farms. The various factors of efficiency, production, and price offset a smaller size of laying flock to bring the labor income per bird to $2.72 on the high farms. The low income farms showed a loss of $0.83 per bird in labor income.

In the breeding farm group the three high farms were much larger than the lowest farms, had a higher egg production per bird, and were more efficient in utilizing labor and investment. Labor cost per bird was $1.03 greater on the three lowest profit farms.

Individual copies of the report have been prepared for each poultryman who cooperated in the project by giving a farm record. Data for these individual farms were entered in the report in order to make comparisons by types of farms and with the high and low profit groups in each type. A summary of the report has been prepared and mimeographed for use in poultry extension meetings.

Milk as a Public Utility. (A. A. Brown and William Kling.) A superficial and historical study of milk as a public utility was reported in the annual report for 1935. The work of 1937-38 confined itself to the legal aspects of milk as a public utility and to a study of duplication of distribution in two areas.

The establishment of state milk control boards is a tacit recognition of the milk industry as a public utility. Winnepeg, Canada, in 1932 definitely recognized milk as a public utility. When the scope of regulation in Winnepeg is compared with that in Massachusetts, no differences are discovered except that no declaration designating milk as a public utility is found in the act establishing the Massachusetts Milk Control Board.

Studies of duplication of distribution were made in two areas. At one apartment house, 7 dealers brought milk each morning to 7 families; in other sample blocks, 15 dealers delivered to 27 families; 8 dealers to 14 families; and 6 dealers to 12 families. In a non-tenement area, a total of 23,500 feet was traveled by 13 distributors on a street 2300 feet long. On another street 3600 feet long, 12 distributors served 27 families. In this same town with 90 miles of streets and highways, milk distributors traveled over 300 miles daily. The average mile was covered 3.5 times, which is low when compared to a duplication of 13 times found in a Milwaukee, Wisconsin, study. Deliveries of individual distributors ran from 3 to 12 quarts per mile traveled.

Waste in distribution is often as much the consumer's fault as the distributor's. Consumer objections to a change in the present method of distribution are many. In the study, 49.5 percent of the people wanted milk delivered between 6 and 8 a. m.; only 40 percent were indifferent as to time of delivery. To conform to this consumer demand would increase the cost factor materially. In the selection of their milk distributor, 36 percent of the people were indifferent; 31 percent liked the shape of the bottle, or the quality of the milk, or had personal reasons for selecting a particular dealer; and 33 percent chose their milkman on the basis of business reciprocity, friendship, or relationship.

Suggested solutions:

I. Possible solutions not involving governmental intervention
    A. Voluntary dealer agreement — diversion of routes
        Producers pool
        Consumers pool
        Joint—producer-consumer
    (If cooperation adds to existing duplication, nothing is gained.)
II. Government intervention
    A. Zoning or allocation of territory
    B. Allocation of routes through licensing
    C. Municipal plants; in combination with A or B

Competitive Factors Influencing the Supply of Market Milk and Cream in Massachusetts. (A. A. Brown and J. E. Donley.) A study of dealers' buying prices, more properly termed product-cost since such designation removes the possibility of confusion with the class prices applicable to all dealers, is nearing completion.

The principal reasons for the variation in dealers' monthly or annual product-cost were; (1) differences in the proportion of Class II milk handled,[1] and (2) type of management.

The influence of the Class II factor varied with the Class I — Class II price ratio. In January when the ratio was 1.73, a variation of one unit in the percentage of Class II handled caused an inverse change of 1.1 cents in the product-cost. In June 1935 with a Class I — Class II price ratio of 3.14, a variation of one unit in the percentage of Class II milk caused an inverse change of 2.4 cents in the product-cost.

The possible importance of the Class I — Class II price ratio is well illustrated by a comparison of the 63 cents spread in dealers' product-costs in June with the 24.7 cents spread for January. Of the 38.3 cents widening in the spread, 5.3 cents can be accounted for by an increase of 4.9 units in the variation among dealers in the percentage of their handlings of milk in Class II and 33 cents by the change in the Class I — Class II price ratio.

The cooperative associations distributing in the market area had the lowest product-costs. Two factors seem to account for this.

Type of management influenced product-costs because cooperative associations may prorate costs or losses among the producer–owner members. The plants operated by the associations were built to handle a larger volume of fluid milk than was being put through them. The difference between designed capacity and used capacity was sufficiently great to be reflected in high unit operating costs that were charged off through a lower product-cost.

Cooperative associations also carried a higher proportion of Class II milk each month than did individually owned plants. A cooperative association cannot drop its producers to adjust its supply to market demands, as proprietary dealers may do. Quite often the cooperative association, in business for mutual benefit, takes on the producer dropped by the individual dealer. The principles of the cooperative association place it at a decided disadvantage as far as milk product-costs are concerned.

Some Economic Aspects of Marketing Fluid Milk in Worcester, Massachusetts. (J. E. Donley and C. W. Smith.) Worcester, the third largest city in New England, is unique in that its milk shed is almost a complete unit, surrounding the city. Also, it is one market in which the Milk Control Board has not established retail prices, probably because there is no serious surplus problem.

Only about 8 percent of the milk consumed in 1935 came from out of state, although most of the cream was produced in other states. Production, unlike that for most other markets, was on a rather even level, varying from 92 percent in January to 111 percent in June, using the annual average production as 100. Although dealers who bought on the flat price plan purchased only the milk they required, they constituted only 13 percent of the market. The dealers who paid for their milk by the use and rating plans had their farmers regulating production sufficiently to prevent an undue surplus on the market at any time.

The November–June ratio usually employed as a measure of seasonal variation of production is definitely not such in this market; for, although the majority of producers shipped more milk in June than in November, the number shipping more in the fall was also large. This difference is somewhat explained by the feeding methods used in Massachusetts as contrasted with those in Vermont and New York.

Another reason for the lack of a serious problem in disposing of surplus milk was the existence of two cream dealers in the city, who were in effect clearing houses for most of the surplus of the regular dealers.

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[1] Class I milk—Milk purchases which dealers dispose of in fluid form.

Class II milk—Milk purchases not needed for the fluid market and disposed of as a milk product; in Massachusetts this generally means sweet cream. (Commonly called surplus.)

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Tobacco Projects. (Walter S. Eisenmenger and Karol J. Kucinski.)

Spacing Experiment. The experiment to determine the comparative effects of different spacing of plants upon the yields and quality of tobacco produced by a large growing strain (211) and by a smaller growing strain of Havana seed tobacco was continued. Planting distances between rows of 36, 39, and 42 inches were used in combination with 12, 15, 18, 21, 24, and 27 inches between plants. Trials for the past three years show that the larger growing strain (211) yielded considerably more per acre than the common Havana seed tobacco and the crop index has been consistently better.

Because of the abnormal rainfall this year, tobacco yields in general have been much less than in the previous years. Because the tobacco has been smaller than usual, 15″ x 36″ seemed the most favorable spacing for yield and crop index for the larger growing tobacco (211). The lowest yields for this tobacco occurred when the spacing was 27″ x 39″, and the lowest crop index with the 24′ x 36″ combination. For the common Havana seed tobacco, the highest yield for 1938 occurred when the spacing was 12″ x 42″ and the highest crop index when the spacing was 21″ x 39″. The lowest yields for the same tobacco were obtained when the spacing was 27″ x 39″ and the lowest crop index occurred with the 21″ x 36″ spacing. Since the past growing season was not typical, in general it can only be said that the larger strain of tobacco (211) should be planted a slightly greater distance apart than common Havana seed tobacco.

Tobacco Grown on Old Sod. Attempts were made to overcome the bad effects from so-called brown root-rot usually witnessed when old hay sod is plowed under preceding a crop of tobacco.

A crop of tobacco was grown on an old timothy sod area which had been previously treated as explained in the following table.

Treatment	Yield and Quality of Tobacco		
	Pounds per Acre	Grade Index	Crop Index
Plot No. 1, sod plowed in mid-summer of 1937 and 200 lbs. of nitrogen added in 1937	1678	.3556	596.7
Plot No. 2, sod plowed in mid-summer of 1937	1552	.3696	573.6
Plot No. 3, 200 lbs. of nitrogen added to sod in 1937 and plowed in spring of 1938	1392	.2986	415.7
Plot No. 4, sod plowed in spring of 1938	1520	.3291	500.2

It was found that the plowing of old timothy sod in the summer previous to the one in which the tobacco was planted was advantageous from the standpoint of yields and crop indexes. The yield and crop index were best where the sod was plowed in midsummer of 1937 and 200 pounds of nitrogen added to aid the decomposition of the sod material. The added growth of hay produced by the addition of 200 pounds of nitrogen on Plot No. 3 in the summer of 1937 may account for the low yield, grade index and crop index of the tobacco grown on that plot.

Brown Root-Rot of Tobacco. It has been observed that tobacco, perhaps more than any other economic plant in this area, is extremely sensitive to the influence of the preceding crop. Plants with a high lignin content, when grown in rotation with tobacco, have a tendency to cause conditions favorable to brown root-rot. It is not to be inferred, however, that the trouble may never arise when tobacco has been grown continuously on a field, or that tobacco may never grow normally when the preceding crop has been one likely to cause the trouble. These exceptions arise at intervals, depending upon the conditions of the growing season. The influence of the preceding crop on the crop yields and quality of tobacco this year is illustrated by the following data.

Preceding Crop	Percentage of Lignin in Tops	Average yield and quality of Tobacco		
		Pounds per Acre	Grade* Index	Crop* Index
Peppers	4.23	1665	.3938	652.3
Horseweed	—	1635	.4060	664.3
Seaweed	9.55	1579	.4007	634.2
Ragweed	2.06	1542	.3991	621.2
Gladiolus	14.41	1538	.3872	601.0
Squash	—	1530	.3606	578.0
Artichoke	3.97	1494	.3731	561.9
Carrots	—	1443	.3330	495.8
Redtop	5.20	1425	.3818	545.7
Turnips	5.74	1386	.3010	448.1
Buckwheat	9.47	1386	.3352	463.5
Cabbage	4.08	1282	.2980	420.2
Wheat	—	1236	.2600	322.0
Kentucky Bluegrass	11.76	1216	.3063	380.2
Tomatoes	11.34	1212	.2896	362.6
Canada Bluegrass	14.15	1118	.2729	334.4
Sweet Clover	10.89	1073	.2344	269.6
Rye	15.16	1030	.2453	282.7
Millet	14.84	989	.2459	252.2
Sudan Grass	13.96	951	.2023	227.9
Alfalfa	11.60	872	.2099	193.4
Red Clover	13.28	850	.2178	230.9
Orchard Grass	7.67	833	.2385	238.0
Sorghum	13.92	731	.2023	153.4

*Grade index, as used here, is a number expressing the grading quality of tobacco produced under the conditions of the experiment. It is based upon the percentage yield of each grade of tobacco and the relative values of these grades given below:

Lights	1.00	Long darks (19″ and longer)	.30
Mediums	.60	Dark stemming (17″ and shorter)	.20
Long seconds (19″ and longer)	.60	Brokes	.10
Short seconds (17″ and shorter)	.30	Fillers	.10

The grade index is derived by multiplying the percentage of each grade of tobacco by the respective rating of the grades, given above, and adding the products.

Crop index, as used here, is a number expressing the crop value of tobacco produced under the conditions of experiment. It is based upon the gross yields of tobacco in pounds per acre and the grade index of the tobacco. Crop index is derived by multiplying the gross yield of tobacco in pounds per acre by the grade index of the tobacco.

Grade index and crop index and the adopted relative values of the different grades of tobacco, as used here, do not necessarily represent current commercial prices of tobacco.

The lignin is recorded not in total quantity left in the soil, but in terms of percentage found in the sample. For example, the total amount of lignin remaining behind when gladiolus is removed is small, although the percentage found in the plant is high. However, as the lignin increases, there is a tendency for yield, grade index, and crop index to decrease.

It would seem that those fields which have little lignin residue from the preceding crops would be desirable for a succeeding tobacco crop.

Rates of Decomposition of Various Bedding Materials. (John Zak and Walter S. Eisenmenger.) The following bedding materials were analyzed for total nitrogen: southern pine sawdust, southern pine shavings, white pine sawdust, cedar sawdust, hemlock shavings, chestnut sawdust, oak sawdust, birch shavings, peanut hulls, and cacao hulls. Each of the materials was mixed with an equal amount of soil (on a dry basis), and sufficient nitrogen added in each case to bring the total nitrogen up to 1 percent. Determinations for rates of ammonification and nitrification were made every two weeks during a period of fourteen weeks. During the first two weeks of decomposition, maple sawdust had the lowest rate of ammonification, followed in order by birch, cedar, oak, and hemlock. Chestnut sawdust had the highest rate. The rates of ammonification of the different conifers followed rather closely a general curve. There was no evidence of nitrate accumulation until after four weeks, when traces began to be found. Reappearance of nitrates at the end of the experiment was due to the decrease in the amount of cellulose present.

In another series, the bedding materials were saturated to 90 percent of their water-holding capacity with cattle urine and left to decompose. Determinations of ammonification and nitrification were made once a month. Lignin determinations were also made at the beginning and end of the decomposition process to study the comparative changes in the various materials. During the first month, birch shavings had the lowest ammonification rate, followed by hemlock and southern pine. Nitrates did not begin to accumulate until the end of the experiment.

From a study of the lignin accumulation, it was found that cacao hulls decompose most readily, followed by birch, oak, chestnut, and peanut hulls. Little lignin accumulation was found when white pine, cedar, and hemlock were used, indicating a slow rate of decay. The following data show the lignin content before and after decomposition expressed in percentages.

	Lignin, Percent		Percentage Change
	Original	Decomposed	
Cacao Hulls	20.83	30.12	44.60
Birch Shavings	17.57	22.98	30.80
Oak Sawdust	26.00	30.29	24.19
Chestnut Sawdust	23.99	29.64	23.55
Peanut Hulls	28.70	34.09	21.60
Cedar Sawdust	27.49	30.98	12.69
Hemlock Sawdust	26.41	29.65	12.27
White Pine Sawdust	24.22	26.07	7.64
Southern Pine Sawdust	26.64	24.75	—7.92
Southern Pine Shavings	26.64	24.53	—7.92
Maple Shavings	22.74	17.98	—20.93

The Use of Nitrogen as an Aid in Decomposing Old Sod. (Karol J. Kucinski, William H. Bender, and Walter S. Eisenmenger.) After the encouraging results obtained last year, the experiment was continued. Calcium cyanamid, at the rates of 100 and 50 pounds of nitrogen per acre, applied to an old sod before plowing in the late fall of 1937 proved to be effective in hastening decomposition, as shown by yields of potatoes, corn, and cabbage. Another area, receiving the same treatment but plowed in the spring of 1938 instead of the fall of 1937, showed similar response to additions of nitrogen, but the yields in general were lower. Determination of ammonia and nitrate nitrogen throughout the growing seasons for the past two years showed that the rate of decomposition of the old sod was faster where nitrogen was plowed under.

Although the differences in yields and chemical analyses between the respective treatments were not so great as those obtained the previous year, because of abnormal rainfall throughout the growing season, the addition of nitrogen to old sods before plowing them under seems to aid in their decomposition and thus lessens their usually harmful effect.

The Absorption by Food Plants of Chemical Elements Important in Human Nutrition. (Walter S. Eisenmenger and Karol J. Kucinski.) Lettuce and cabbage were grown on soil to which the cations, sodium, potassium, magnesium, and calcium, were added at the rate of 500 parts per million per individual plot. The anions, chlorine, bromine, iodine, sulfate, and phosphate, were used on additional plots at the rate of 200 parts per million.

From the chemical analysis, the following increases for the aerial portions of lettuce and cabbage and for the roots of lettuce were observed and recorded on a percentage basis.

	Lettuce Tops	Lettuce Roots	Cabbage Tops
		Cation Increase	
CaO	6.3	16.1	16.0
MgO	58.5	19.9	43.6
K_2O	58.7	78.7	18.0
Na_2O	37.2	41.7	55.4
		Anion Increase	
P_2O_5	56.6	46.5	43.0
SO_3	28.4	61.5	84.9
Cl	83.9	83.6	83.9

The order of intake of potassium in cabbage and lettuce was remarkably different, as was sulfur. The Cruciferae are noted for sulfur compounds. Chlorine was remarkably consistent in intake for the two types of plants and the parts of each plant. It would seem that different soils cause different amounts of elements to be taken in by plants according to the available amounts present. Also, intakes of elements by plants are dependent upon the semi-permeable membranes, which differ in different types of plants.

Magnesium Requirements of Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) A plot of land known to be deficient in magnesium was divided into four sections and treated as follows: no treatment, magnesium alone, magnesium plus lime, and lime alone. A number of different species were then planted across the sections to study the reaction of each to the different treatments.

Chemical analyses show that, with few exceptions, plants receiving magnesium salts contained more magnesium in the vegetative tissue; but the application of lime had no effect on the content of calcium. The composition of the seeds with respect to both magnesium and calcium was relatively constant regardless of treatment. However, there is some evidence that the addition of magnesium salts to soil reduces the potassium content of seeds. Results showed that if magnesium deficiency symptoms appear after plants have made considerable growth, little is to be gained by subsequent application of magnesium salts to the soil. The photographs show the advantageous effects of a 150 pound application of magnesium sulfate to a magnesium deficient field.

Tobacco grown on land deficient in magnesium was of inferior quality, having poor color and very poor leaf texture. The sorting data show that both grade and crop indexes were better where magnesium was applied, either alone or with lime.

Investigation with Various Winter Cover Crops for Onion Fields. (Karol J. Kucinski and Walter S. Eisenmenger.) Onion growers in the Connecticut Valley do not as a rule use a winter cover crop on their onion fields because it is desirable to plow their fields in the fall in order to plant the onions as soon as the fields are free from frost in the spring. This practice is responsible for the sheet erosion and especially for the excessive dust storms which are witnessed during late fall and early spring. The usual winter cover crop of rye as used on tobacco fields, if seeded on an onion field, would necessitate spring plowing and thus retard the early onion planting which is so desirable.

In this investigation, buckwheat, spinach, barley, oats, spring wheat, and spring rye were seeded this fall on plowed onion land in the hope of finding some kind of plant, and a date and rate of seeding, which will produce a desirable winter cover and yet winterkill so as not to interfere with the early planting of onions.

Relationships of Natural Vegetation to Physico-Chemical Properties of Soils in Massachusetts. (Walter S. Colvin and Walter S. Eisenmenger.) It has been discerned by both ecologists and farmers that some types of vegetation on land can be used as an index of the land's potentiality. Four factors were chosen for investigation: plant type, soil type, water-holding capacity of soil, and pH of soil, in the expectation that a relationship would be found between some of these factors.

More than 425 sites have been chosen for the investigation, and the natural vegetation on these has indicated by frequency of occurrence that positive results can be obtained. Abundance of certain natural growing plants occur in areas where land values never have been high; and other types of plants predominate where the land is valuable even in times when agriculture as a business is not an exceedingly profitable enterprise.

Investigation of Soil Erosion in Massachusetts. (Karol J. Kucinski and Walter S. Eisenmenger.) It has been felt for some time that, before any study is made of the ways of controlling soil erosion within the State of Massachusetts, there should be a preliminary investigation to determine the extent of erosion present and whether soil management practices and cropping systems now in use are generally adequate for its prevention. Accordingly, considerable time was spent during the past year traveling throughout the State, making careful observation of the different types of soil erosion and noting in particular the causes which brought it about. Many farms in practically every town in the State were visited in detail and visual observations for soil erosion were relied on almost wholly. Photographs of the different types of erosion were taken, and notations were made as to the frequency of occurrence, type of soil, slope, area, drainage conditions, methods of cultivation, and kind of crop grown.

In summarizing this investigation, it was found that accelerated soil erosion, which is differentiated from geological erosion beause it is brought about by the action or carelessness of man, is not a major problem in the agriculture of the State. It can and should be controlled. Individual cases of sheet, gully, and wind erosion were found scattered everywhere within the whole State. Sheet erosion was the most common form and was observed on cultivated slopes of 10 percent or more. Frequently either carelessness or poor farm management was responsible for sheet erosion. Wind erosion was found mainly in the Connecticut River Valley and the Cape Cod section. Flood erosion of the more devastating nature was found along the Connecticut, Merrimack, Blackstone, and Housatonic rivers.

Soil erosion within the State can be easily controlled if measures are taken to help the individual farmer to overcome his particular soil erosion trouble. The correct and more extensive use of cover crops, proper rotations with sod, strip farming, and contour cultivation would aid greatly, where feasible, in totally eliminating any soil erosion.

This investigation was carried out in cooperation with the Soil Conservation Service of the United States Department of Agriculture. A more detailed report has been submitted to the cooperating agencies in Washington.

Onion Blast. (W. G. Colby.) The onion disease known as blast occurs frequently in the Connecticut Valley. It is specifically a disease of the tops of onions, but has a marked consequent effect on the yields and quality of bulbs.

The onions in the Valley have been affected severely by blast during the last two seasons. In 1938 only seed onions were much affected; in 1937, however, the disease developed considerably earlier than in 1938 and caused serious injury to the tops of set onions as well as an early, premature dying of the tops of seed onions. The yields of set onions were much reduced by the attack of blast in 1937, and much of the loss caused by rot, both at time of harvest and subsequently in storage, seemed to be directly attributable to the deleterious effects of the blast on the growth and formation of the bulbs. The yields of seed onions were greatly reduced by the smallness of the bulbs produced as a result of the premature death of the tops.

The cause of blast has been the object of many field observations and experimental trials by research workers at this station for more than ten years. In 1931 Jones (Annual Report, Mass. Agr. Expt. Sta. Bul. No. 271, p. 243) reported from greenhouse experiments that an injury resembling blast could be induced by subjecting plants to reduced light, high relative humidity, and a wet soil for a period of ten days and then exposing them for a few hours to intense sunshine and an atmosphere of low relative humidity. Later in the same year, Doran and Bourne (Mass. Agr. Expt. Sta. Bul. 279), as a result of many field observations and trials, expressed the opinion that, "These and other considerations indicate . . . a physiological rather than a parasitic cause of onion blast." The writer, too, after making careful field observations during the severe "blast years" of 1937 and 1938, reached essentially the same conclusions. The opinions expressed here are for the most part elaborations of ideas previously expressed.

The environmental conditions producing blast were so typical in 1938 and the resulting blast so severe, that it was thought desirable to report in detail the manner in which the trouble developed. During the month of June, over 8 inches of rain fell and the mean daily temperature was slightly above normal. Onions, both from sets and from seed, made a vigorous, healthy, dark-green top growth and gave excellent promise of a bumper yield until about June 21. A week of cloudy, rainy weather from June 11 to June 18 was followed by hot, clear weather which began June 19 and continued until June 26. Blast symptoms first appeared about June 21 on onion seed sets and on seed onions planted on light soil. The blast began on the lighter soils along the river banks and spread back toward higher terraces. Seed sets and seed onions on other light soil areas blasted at this time also. Blast was first characterized this year, as usual, by the appearance of small white spots on the leaves, followed by a dying back from the leaf tips.

By June 25, virtually all seed sets were badly affected, many fields of seed onions partially affected, and some fields of set onions beginning to die back from the tips. A heavy rain on June 26, 27, and 28 checked the progress of the blast on almost all areas. Ten days of cool weather, following these rains, permitted the set onions to mature fully without appreciable injury and allowed the seed sets in most instances to "size up" sufficiently to be pulled, even though they had been badly affected by blast. This was particularly true where fertilizer topdressing had been applied to seed sets before the June 26th rain. A good crop of seed sets was harvested in almost all instances.

During the period June 28 to July 8, the seed onions made good top growth and had begun to form bulbs. Even in those areas where the blast had made its appearance earlier, the bulbs made good growth, and at this time, prospects were excellent for a good crop of seed onions. Of course, small areas on light land, particularly land flooded in 1936, made little recovery and indicated that they would be a total loss. A period of warmer weather followed from July 8 to July 17 but the progress of blast on seed onions was not rapid. On July 17, however, a maximum temperature of 87° seemed to induce blast symptoms again in practically all seed onion fields. Between July 18 and July 25, some five inches of rain fell, with only one rainless day. The relative humidity was high at all times, and the few hours of sunshine which occurred during the week seemed to greatly accelerate the spread of blast symptoms. Clear, hot, humid weather on July 25 and 26 followed this rainy week and greatly increased the severity of blast in all seed onion fields. Even fields of onions on the higher terraces in the vicinity of Amherst, which seldom show the effects of blast until much later than Valley fields, were seriously affected at this time. In no instance, as a result of blast, was either the yield or the quality of a field of seed onions much more than 40 to 50 percent of what could be considered a good crop. Set onions had reached maturity before this date and as a result there was little damage to them from blast.

In the opinion of the writer, what principally happened to the onion crop of 1938 is as follows. The heavy rains and high temperature during the first part of June resulted in a rank vegetative top growth accompanied by a relatively small and shallow root system. The hot, dry weather toward the end of June resulted in excessive transpiration from the rank vegetative tops, so that the root system was unable to maintain normal water relationships within the plants. As a result of this abnormal physiological condition, blast symptoms began to appear and as the hot, clear weather continued, the spread of blast was rapid and its severity increased. The reason that blast spreads and does not appear simultaneously on all areas is because in some soil types, the onion root system is able to maintain an adequate supply of water to the leaves for a longer time period than in other soil types. The greater leaching of plant food nutrients, as a result of the heavy, early-June rain, from some soils (particularly sandy soils) than from others was also a factor influencing the "spread" of blast in 1938. It appears that when excessive leaching losses are experienced in June, blast will appear first on the "light" sandy soils. On the other hand, if June leaching losses are not excessive, the proportionately greater top growth and also shallower root system of onions on "heavy" soil will result in blast appearing there first.

The rains of June 26-28 followed by ten days of cool weather greatly reduced transpiration rates and permitted the reestablishment of normal water relationships within the plant and "recovery" from blast resulted. The fact that seed onions at this time were still in a relatively early stage of growth also facilitated recovery.

When the sequence of weather conditions of the latter part of June were duplicated during the latter part of July, the seed onions behaved then much the same as they had earlier in June. On the hot, clear days of July 25 and 26 following a week of cloudy, rainy weather, the water relationships within the plant were so violently disrupted that the onion tops in all fields of seed onions simply dried up. In this case very little recovery resulted and seed onion bulbs grew little if any after July 25.

The weather conditions, then, which usually favor the extensive development of blast include wet weather in June, followed in July by a period which includes a few days of cloudy, humid weather succeeded by a few clear, hot, dry days. In previous years, this period in July has usually begun about the third week when seed onion bulbs have reached about half their potential size.

In checking through the Experiment Station Meteorological Observations over the past eleven years, it was found that whenever a sequence of weather conditions occurred similar to that described above, serious damage from blast resulted. Such weather conditions existed during the growing seasons of 1927, 1928, 1931, 1935, 1937, and 1938, and blast was prevalent on seed onions to a serious extent each of these seasons.

Besides these weather conditions as the primary cause of blast, there are other contributing factors. Foremost of these is injury from onion thrips. These insects not only may weaken the plant so that it is more susceptible to blast but may so further weaken the plant after the effects of a mild attack of blast are gone that recovery is impossible. For example, in 1938 very few thrips were present when blast symptoms appeared in June, but in July when blast symptoms reappeared, thrips were abundant. The thrips population at this time was so great that even had the plants been able to withstand the effect of the blast, the added injury from thrips would have made recovery impossible. Onion thrips then may play an important role in preventing recovery after weather conditions producing blast have gone. By the time in July when blast usually strikes, set onions have about reached maturity and harvesting operations have begun. The thrips tend to migrate over from the matured set onion tops to actively growing seed onion tops and thereby build up a high thrips population. Severe thrips injury to seed onions consequently develops. Other contributing factors favorable to the prevalence of blast include root diseases (primarily pink root, *Phoma terrestris*) and lack of available plant food as a result of heavy seeding or excessive leaching losses. In short, any factor or set of factors which adversely affects the vitality of the onion plant will favor the development and increase the severity of onion blast.

It can be seen that the occurrence of blast in six out of eleven years has created a very serious situation with respect to the growth of seed onions in the Connecticut Valley. These "blast" years have resulted in large financial losses to growers and have greatly reduced acreages of seed onions.

Permanent Pastures. (W. G. Colby.) Results from outlying fertilizer topdressing experiments in Worcester County, Massachusetts, together with numerous observations on other permanent pastures throughout the State, lead to the conclusion that at best fertilizer topdressings on old pasture sods will only bring these sods up to a moderate level of productivity. Even at this productivity level, herbage production is seasonable. Herbage yields reach peaks in early summer and early fall and drop to low levels in midsummer and late summer.

The first limiting factor to the presence of white clover in old pasture sods is moisture. Native white clover can be found widely distributed after wet seasons, but after dry seasons it will be found only in areas where good moisture relationships have been maintained throughout most of the growing season. Lack of available mineral elements, also a limiting factor to the prevalence of white clover, is as important as favorable moisture relationships from the standpoint of yield. In pastures where native white clover can be depended upon to supply nitrogen, response to complete mineral (calcium, potassium, phosphorus) fertilization will be pronounced.

In pastures where white clover cannot be depended upon to supply nitrogen, this element is the first limiting element, and is ordinarily followed in turn by calcium (lime), potassium, and phosphorus. In such cases, a system of fertilization which includes nitrogen as well as complete minerals will be necessary to produce a pronounced response.

Reseeded Pastures. (W. G. Colby.) Reseeded pastures in the sense discussed here refer to areas which are tilled, fertilized, and reseeded to the more productive pasture species. Observations clearly indicate that before a potentially high-yielding species, Ladino clover for example, can establish and maintain itself, a relatively high level of soil fertility must be provided. To attain such a fertility level in most crop soils in Massachusetts, it is necessary to incorporate fertilizer materials and organic matter into the soil in liberal quantities by some sort of tillage operations. High-yielding species can then be expected to produce pasture herbage commensurate with their potential yielding capacity.

Highly productive species will persist and remain in a high state of productivity just so long as it is possible to maintain a high level of soil fertility. With the aid of annual fertilizer topdressing applications, a relatively high level can be maintained in most instances from three to five years. To reattain the initial soil fertility level, it is then necessary to repeat the tillage, fertilizer, and seeding practices. If reseeding operations are not carried out after three to five years, Kentucky bluegrass, native white clover, and various Agrostis species will become the dominant herbage plants.

The problem of herbage production in Massachusetts centers mainly around soil fertility. If other factors such as weather, physical soil conditions, and management practices are reasonably normal, not only the maintenance of particular species in many cases but also the herbage yields of all species are primarily functions of soil fertility. The struggle in Massachusetts is to provide a level of soil fertility which will maintain high-yielding species, such as Ladino clover. Fertilizer topdressing alone will not accomplish this result. Tillage, fertilizers, organic matter, and seed are all important factors in establishing and maintaining productive species in productive pastures. If pastures are cared for and treated as any other high-producing crop, they will yield in a comparable fashion.

Trials of Thirteen Different Hay Seeding Mixtures. (Ralph W. Donaldson, Walter S. Eisenmenger, and Karol Kucinski.) Data obtained at the end of three years from two cuttings per year of various seeding mixtures on soil limed for alfalfa indicate the following: (1) A number of mixtures show no significant difference. No single one is outstanding. (2) The mixtures totaling 18-21 pounds, comprised of alfalfa 6-18 pounds, with the balance made up from red clover 3-6 pounds and timothy 3-6 pounds, have tended to produce the highest yield. (3) Orchard grass in mixtures, while yielding comparatively well in new stands, has reduced the percentage stand of alfalfa plants in subsequent years and also matures too early for use with alfalfa. (4) Redtop, possibly satisfactory with timothy and clovers, appears less desirable when alfalfa is included, because of its denser growth. (5) A 21-pound rate of seeding averaged 250 pounds more hay than a 17-pound rate and 800 pounds more than a 13-pound rate. (6) Of most significance in maintaining yields in these trials was a topdressing of 250 pounds of potash (60 percent) per acre, applied on half of all plots the two previous seasons, which in 1938 harvests resulted in a 46 percent increase in yield.

The Effect of Time of Cutting on Yields of Alfalfa and the Use of Potash in Preventing Winterkilling of Alfalfa. (Karol J. Kucinski, Walter S. Eisenmenger and Ralph W. Donaldson.) This experiment has been continued for the past three years. Mowings of alfalfa were made at definitely spaced intervals of time to determine the best management practice for alfalfa growing. Some plots were cut three times and others were cut twice per season, beginning in early June and extending to late September. This year, as in the past two, the higher yields were obtained on those plots having a schedule of three cuttings, although the difference in yields between the plots cut three times and those that were cut twice was not as great as in the past two years. The stand of alfalfa in the fall where two cuttings were made was generally superior to that where three cuttings were made. Portions of each plot, which did not receive any potash, did not withstand the elements of winter and nearly all of the alfalfa has been winterkilled and replaced by a thick stand of volunteer grass and weeds.

Alfalfa Variety Tests. (Walter S. Eisenmenger and Karol J. Kucinski.) In cooperation with the U. S. D. A., 15 strains of alfalfa seeded in 1935 have been continued as a basis for yield and longevity studies. The Grimm variety was used as standard check.

The longevity of the varieties, based on observation made in the spring, may be tentatively rated as follows:

Better than Grimm (Check)	Same as Grimm	Poorer than Grimm	Least Adapted
Hardigan	Ont. Variegated	Arizona Common	Argentina
Hungarian	Dakota Common	Utah Common	Hardistan
Italian	Cossack	Kansas Common	Ladak
New Mexico			Turkistan

Effect on pH from Adding Sulfur to a Soil. (Ralph W. Donaldson, W. G. Colby, and Hrant M. Yegian.) Ordinary finely ground sulfur was applied in 100, 250, 500, and 1,000 pound rates per acre to a soil of very fine sandy loam texture with initial pH of 6.5. The effect on soil pH was observed during an 87-day period (March 16-June 11, 1938) in triplicate pot trials under greenhouse conditions of temperature and reasonably high moisture. Readings started 10 days after the sulfur was applied, and were recorded at weekly intervals, using a Beckman glass electrode potentiometer.

Definite change in reaction was already apparent in 10 days and was virtually complete by the end of 30 days. Additions of sulfur to this soil tended to lower the pH in fairly direct proportion to the amount of sulfur applied. The decrease per unit of applied sulfur was smaller, however, as larger applications were made. The amount of pH change effected by each increment of sulfur, compared with that of the untreated soil, is shown as the average difference for all readings, as follows:

Rate of Sulfur Application	Average Reduction in pH Readings for the Period March 26-June 11
100 pounds	.169
250 pounds	.386
500 pounds	.689
1,000 pounds	1.159

Potato Variety Trials. (Ralph W. Donaldson, Walter S. Eisenmenger, and Karol Kucinski.) Trials of 8 varieties were made at the college. Two of the newer varieties, Houma and Warba, yielded well. Chippewa, which in other seasons has ranked high in these tests, this season gave low yields, possibly because of leaf roll. In order of rank, the 8 varieties are as follows: Green Mountain, Houma, Warba, Russet Rural, Cobbler, Katahdin, Chippewa, Golden.

The Comparative Nutritive Effects of Copper, Zinc, Chromium, and Molybdenum. (H. Robert DeRose, W. S. Eisenmenger, and W. S. Ritchie.) Buckwheat and barley were again grown in white sand cultures, using Knops' nutrient solution, to which the elements copper, zinc, molybdenum, and chromium, were added. The sand used was shown to be free of any contaminating metals by spectrograhic analysis, conducted by the workers in the laboratories of the United States Department of Agriculture in Washington.

The addition of small amounts of copper and zinc (less than 5 p.p.m.) had a stimulating effect, increasing the total dry weight of the buckwheat. Any amount above 5 p.p.m. of copper and 10 p.p.m. of zinc had a depressing effect, decreasing the total dry weight of the plant as well as adversely affecting the root system.

Molybdenum had a stimulating effect on buckwheat up to 10 p.p.m., beyond which the total dry weight of the plant was decreased as was the general size of the root system.

Results obtained with the barley plant with copper and zinc were the same as for the buckwheat plant. Barley was more tolerant to molybdenum than buckwheat, for the maximum dry weight was obtained with 40 p.p.m.

Chromium had little if any stimulating effect on barley in small quantities, while larger quantities (40 p.p.m.) killed the plants.

Further Studies with Calcium Cyanamid as a Weedicide. (Lawrence S. Dickinson and Hrant M. Yegian.) On a Merrimac soil type, effective control of crab grass was obtained in an established Kentucky bluegrass lawn, known to be heavily infested with crab grass seed. On plots receiving a single application March 1, 10 to 15 pounds per 1,000 square feet gave the most effective control of crab grass. Slightly better control of crab grass and less injury to the lawn, however, resulted from two applications (10 pounds per 1,000 square feet on March 1, followed by 10 pounds on June 5) than was obtained from the single 15-pound application on March 1. June 5 is just prior to the normal germinating time of crab grass at Amherst.

As a preseeding weedicide to control crab grass, calcium cyanamid, raked into the surface two inches of the graded lawn at the rate of 20 pounds to 1,000 square feet, reduced the crab grass population to a practical minimum.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in Cooperation with the Massachusetts Agricultural Experiment Station

C. V. Kightlinger, U. S. D. A., in Charge

Black Root-Rot. (C. V. Kightlinger.) This project to improve Havana Seed tobacco was begun several years ago. The objective and the plan of work were both given in last year's Experiment Station Annual Report. No important changes have been made in either since the project was begun, although its different phases have been stressed in progressive order, and the work done has been varied as circumstances and needs of the problem necessitated.

Many new strains of Havana Seed tobacco have been produced during the course of the project. A large number of these strains have been tested experimentally, and several of them have been found to possess much merit.

The most promising of these new strains is Havana Seed 211. It is highly resistant to black root-rot. In general appearance it closely resembles common Havana Seed tobacco. It is a good producer with respect to both amount and quality of tobacco produced and it withstands drouth considerably better than most strains of common Havana Seed tobacco do. It has been observed also that flea beetles and thrips do not attack Havana Seed 211 so readily as they do common Havana Seed tobacco.

In small plot tests conducted for six years under favorable producing conditions where black root-rot was not an important factor, Havana Seed 211 averaged 2214 pounds of tobacco per acre and outyielded the common Havana Seed control by 164 pounds per acre, or 8 percent. It outgraded the control by approximately 12 percent. On the basis of both yield in pounds per acre and quality of tobacco produced, it surpassed the control by approximately 21 percent. In other small plot tests conducted for five years under black root-rot promoting conditions, Havana Seed 211 averaged 1938 pounds of tobacco per acre and outyielded the common Havana Seed control by 607 pounds per acre, or approximately 45 percent. It outgraded the control by approximately 45 percent. On the basis of both yield in pounds per acre and quality of tobacco produced, it surpassed the control by approximately 88 percent.

Havana Seed 211 has been grown to a limited extent commercially. It commonly has outyielded and outgraded common Havana Seed tobacco when they were grown under comparably favorable producing conditions. Under black root-rot promoting conditions, it has far surpassed common Havana Seed tobacco with respect to both amount and quality of tobacco produced.

A majority of the growers of Havana Seed tobacco in the Connecticut Valley who have grown Havana Seed 211 approve of the strain in its present stage of development. And it is acceptable to one group of tobacco buyers in the Connecticut Valley. However, another group of buyers admit freely that the strain possesses much merit but suggest that it be modified in certain respects to make it more acceptable to them.

So, recognizing the close approach which Havana Seed 211 makes toward fulfilling the objectives of the project, and using the strain as a foundation stock, work has been done during the last two years to improve upon the strain in accordance with the suggestions made by the latter group of buyers. This was first attempted by selecting within Havana Seed 211 certain plants which seemed possibly to possess the desired characteristics. The progeny of these selections are now being grown to determine whether any of them possess the desired characteristics in sufficient degree to satisfy the criticisms made of Havana Seed 211. And secondly, in order to provide new strains for use in the project in case the selections made with Havana Seed 211 fail to provide the desired improvements, numerous crosses have been made between the most acceptable selections and three highly approved strains of common Havana Seed tobacco. The progeny of these crosses are now being grown for the purpose of selecting new strains which may possess the desired characteristics. The selections made from the crosses will be tested in due time to determine their worth. By these procedures it is hoped to produce strains of Havana Seed tobacco which are improvements over Havana Seed 211 and which may more nearly satisfy those who criticise Havana Seed 211.

Reductions in Yield and Quality of Tobacco Caused by Mosaic. (C. V. Kightlinger.) Experiments were made in 1936 and 1937 to determine and to compare the reductions in yield and quality of Havana Seed tobacco in the Connecticut Valley caused by common tobacco mosaic. Four inoculations for mosaic were made at successive 15-day intervals each season, beginning as soon after the time of setting the tobacco as it was possible to inoculate the plants. The inoculum used in the experiments was obtained by expressing juice from mosaic-diseased tobacco plants, and it was applied to the leaves of the plants to be inoculated by means of the fingers. Except for the difference in time of inoculating the plants, uniform treatments were employed throughout the experiments each season.

By summarizing the experimental results for the two years, it was found that mosaic infection resulting from the inoculations reduced the yield of tobacco below that grown on the control plots, which was 1924 pounds per acre. Quality and value of the tobacco were also reduced as follows:

Time of Inoculation	Reduction due to Mosaic Infection		
	In Yield Percent	In Quality Percent	In Value Percent
At time of setting...........	30	28	50
15 days after setting.........	25	22	42
30 days after setting.........	16	14	28
45 days after setting.........	10	10	19

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

The Effect of Feeding a Vitamin A Concentrate on Growth and Reproduction in Dairy Cattle. (J G. Archibald and C. H. Parsons.) The final detailed report on this project has been prepared and will be published as an experiment station bulletin.

The results obtained, although favorable to the vitamin A concentrate in their general trend, were not marked. It should be borne in mind, however, that the cows were on better-than-average rations, some of them being fed for Advanced Registry records. It seems reasonable to assume that response to the concentrate might be more marked under average farm conditions than it was in this case.

It seems justifiable to recommend for average New England conditions the inclusion of some form of supplemental vitamin A in the rations of dairy cattle during that period of the year when they are not on pasture. The practice will be of most value on farms where silage is not fed and the hay is of poor quality. If New England dairymen could feed good quality alfalfa hay through the winter and if they could always be sure of having well-preserved corn silage stored before frost, it is probable that their cows would not need additional vitamin A. But since for most of them such a state of affairs is not attainable, some other source of the vitamin must be relied upon.

The Effect of Complex Mineral and Vitamin Mixtures on Milk Production, General Health, and Reproductive Efficiency in Dairy Cattle. (J. G. Archibald.) The feeding trials connected with this project were brought to completion during the year, and records extending over a period of two years are in process of detailed study. Conclusions cannot be drawn at this time, but from superficial observation the animals receiving the supplements do not appear to be superior to those in the control groups.

A Study of the Mineral Elements of Cows' Milk. (J. G. Archibald and C. H. Parsons.) Supplemental phosphorus in the form of disodium phosphate, fed to a group of eight cows in the college herd during the winter of 1937-38, increased the phosphorus content of their milk only slightly (from .089% when they did not receive it to .090% when it was fed daily in their grain ration). This slight increase was not significant. The averages are based on 96 determinations of the element in the milk — 48 when the cows were receiving the supplement and 48 when they did not receive it.

This season the effect of supplemental iron on the iron content of milk is being studied.

The Effect of Artificial Light on Milk Production. (J. G. Archibald and C. H. Parsons.) The preliminary trials on this project have been completed. During the winters of 1936-37 and 1937-38, two Guernsey cows were alternately exposed to the direct rays of a 1000-watt electric light throughout the hours of darkness for successive 30-day periods. These cows were similar in age, breeding, and stage of lactation and were handled identically except for the exposure to light. Their production records, when converted to a 4 percent fat basis, showed greater production (1.43% the first year and 0.64% the second year) during the periods when they were exposed to the strong light than when they were kept under ordinary conditions.

Studies in the Chemistry of Pasture Grasses. (J. G. Archibald.) The chemical studies originally planned for this project were brought to completion during the year and correlation and interpretation of the results are in progress. The palatability tests with cows were repeated this season and extended to the second series of plots. The results substantiate those obtained last year. The cows showed a decided preference for timothy, the bent grasses (*Agrostis* spp.), and orchard grass; they were quite indifferent to bluegrass as long as the others were in good supply; and they left sheep fescue (*Festuca ovina*) practically untouched. The verdict of the cows confirms the judgment of the nutritive value of the grasses based on their chemical composition.

The Vitamin Content of Certain Pasture Grasses. (W. S. Ritchie and J. G. Archibald. Cooperative with Chemistry.) This project has been completed. The report appears under the Department of Chemistry.

Investigation of the Merits of Legume and Grass Silage for Massachusetts Agriculture. (J. G. Archibald and C. H. Parsons.) The feeding trials conducted during the winter of 1937-38 showed that this type of silage was equal to corn silage and superior to dry hay for milk production. Flavor and carotene content of the milk were improved.

No difficulty was experienced in getting the cows to eat the silage. Two lots of it stored in 1937 consisted largely or entirely of alfalfa. The cows relished the alfalfa silage keenly and increased somewhat in their milk flow while it lasted. Experience thus far in feeding such material, however, leads to the belief that it cannot completely take the place of dry hay. The cattle seem to crave dry roughage after they have been without it for a time.

In June of this year approximately 80 tons of the material were preserved with molasses and 117 tons were stored in another silo with phosphoric acid (18 pounds to each ton of green grass) as the preservative. At date of writing (December 1938), the phosphoric acid silage is being fed in comparison with corn silage. Later in the winter it will be compared with the molasses silage.

The phosphoric acid silage seems to be quite well liked by the cows, but it has not kept as well in storage as the molasses silage did last year. Flakes and pockets of mold are encountered rather too frequently, but this may possibly be due to the type of silo (a square concrete structure with rough inside walls) rather than to inefficiency of the preservative.

A bulletin dealing with all phases of the subject of legume and grass silage will be available for distribution before silo-filling time next June.

The Value of Dried Citrus Pulp for Dairy Cows. (J. G. Archibald.) The development of the canned citrus fruit and citrus juice industry in the United States during the past few years has resulted in the production of a new by-product feed known as dried citrus pulp. This material consists of the dried and processed cannery residues, chiefly rinds, seeds, and "rag" (the technical name for the white network inside the rind and between the sections of the fruit), together with such cull whole fruit as is unmarketable or unsuitable for human food. Depending on its point of origin, it may come chiefly or entirely from oranges or grapefruit, or may be a mixture of both.

Although both the unprocessed "green" pulp and the dried commercial product have been fed to various classes of livestock in California, Florida, Georgia, and Texas for several years, the dried pulp made its first appearance in New England feed markets early in 1938. It has come into this region chiefly as a competitor of dried beet pulp in the ration of milking cows. Analyses show it to be strictly a carbohydrate feed.

Information on its value for milk production is limited. Favorable results are reported from California and Florida, but in both cases the number of cows used was small. No evidence is available concerning its value under New England conditions of feeding and management. It was therefore decided, when it first reached our markets a few months ago, to conduct an extensive feeding trial of its merits with a large number of cows. Through the courtesy of officials in the State Department of Mental Health it has been possible to conduct such a trial in the herd at the Belchertown State School.

Thirty-eight purebred Holstein cows were divided into two groups and were fed dried citrus pulp and dried beet pulp by the double reversal method over a period of 86 days (60 days actual trial; 26 days preliminary). Some difficulty was experienced in getting the cows to eat the citrus pulp, although it was moistened and some molasses added to it.

Comparative effect of the two rations was noted on general condition of the cows, gains in live weight, and milk production. In all these respects there was a slight difference in favor of the beet pulp, but it was significant only for gain in weight and then only barely so.

It would seem that, with the exercise of some care and patience in getting cows accustomed to the citrus pulp, it should prove a satisfactory substitute for beet pulp in their rations. Because of its carbohydrate nature, if much of it is fed, the protein content of the grain ration should be higher than otherwise. Citrus pulp is heavier than the type of beet pulp ordinarily fed in New England and soaks up less water. Anyone unaccustomed to feeding it should rely on weights rather than on measures at first.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

The research work of the department is divided between two general topics: one being the bacteria of water, and the other intestinal bacteria important in nutrition. The research program on the bacteriology of drinking water was outlined in the annual report for 1937 (Mass. Agr. Expt. Sta. Bul. 347:26, 1938). Some new work has been undertaken in the bacteriology of swimming pool water, including a study of the influence of swimming load on the numbers of streptococci and on the ratio between streptococci and coliform bacteria, as well as a study of the streptococci to determine their source.

The test for coliform bacteria (*Bacillus coli* group) is used, as with drinking water, to indicate the sanitary quality of the water used to fill swimming pools. When pool water is treated by some purification process, usually chlorination, the presence of coliform bacteria may be interpreted as indicating contamination of the water by those using the pool.

Authorities are giving attention also to streptococci present in water as evidence of contamination, both in drinking water supplies and in swimming pool water. Streptococci do not survive as long in water as do coliform bacteria. The presence of streptococci, therefore, can be interpreted as evidence of comparatively recent contamination. The streptococci can be differentiated by laboratory methods to give some idea of their source, whether they come from the intestinal tract or from the nose and throat. If they are from the intestinal tract, they have the same significance as the coliform bacteria. If they are from the nose and throat, they may indicate possible danger of nose, throat, or sinus infections among pool users. Both types may be found in pool water at the same time.

Following are reports of studies made during the year.

Influence of Bile and Bile Salts on Aerobacter aerogenes. (James E. Fuller.) This study has been published in the Proceedings of the Society for Experimental Biology and Medicine, Vol. 38, pp. 507-510, 1938.

Salt Tolerance of Fecal Bacteria. (James E. Fuller and R. H. Guiberson.) This is a study of the salt (sodium chloride) tolerance of streptococci isolated from feces as influenced by carbohydrates, bile, and reaction of the medium. The object is to obtain results that may assist in differentiating these streptococci in order to evaluate their sanitary significance. A similar study is being made of the coliform bacteria, for comparison with results of the streptococcus study.

Studies completed have shown that members of the streptococci isolated from feces are classified as forms from the nose and throat (by accepted physiological reactions). Salt tolerance tests of coliform bacteria showed that *Escherichia coli* tolerated 9.5 grams of salt per 100 millilitres of nutrient broth; *Aerobacter aerogenes* tolerated 9.0 grams of salt per 100 millilitres of broth; and certain intermediates tolerated no more than 8 grams of salt per 100 millilitres of broth. Tolerance was indicated by visible growth. It was possible to recover living bacteria from all cultures up to the limit of salt concentration employed, 11 grams of salt in 100 millilitres of broth. This portion of the experiment will parallel that with the streptococci by determining the influence of fermentable carbohydrates, bile salts, and different media reactions.

A Study of the Eijkman Test. (Ralph L. France.) This test for the sanitary quality of water is based upon the claim of its originator that only *Escherichia coli* definitely significant of sewage contamination will produce acid and gas in dextrose broth at 46° C., and that less significant members of the coliform group will not do so. More than three hundred coliform bacteria cultures were cultivated in Eijkman's dextrose broth at several temperatures (46°, 45°, 44°, 43°, 41°, and 39° C.). The bacteria represent *Escherichia coli*, *Aerobacter aerogenes*, and intermediates of the group selected on the basis of standard tests (Voges-Proskauer, Methyl red, and sodium citrate). It was anticipated that the use of the several temperatures might aid in grouping these bacteria with reference to their relative sanitary significance. It was found, however, that only *Escherichia coli* was selected by the procedure. This was in agreement with the usual interpretation of the test. There appeared to be no relationship, among other strains, to their differential reactions.

Streptococci in Swimming Pool Water. (Ralph L. France.) A comprehensive study of the water of the college pool during times of heavy use revealed that a majority of the cultures isolated were not of intestinal origin but were from the mouth and nose. The numbers increased rapidly with the increase of the swimming load, and decreased rather quickly after the swimmers had left the pool. The water of the pool is treated with chlorine. Further study is planned on the college pool and other available pools. A study of this kind is important because of the popularity of swimming pool use in schools and colleges, and in public parks and other recreation areas.

Intestinal Bacteria Important in Nutrition

Studies of intestinal bacteria are being made in cooperation with the Nutrition Laboratory and with Home Economics Research. It is claimed by many authorities that bacteria which decompose protein food waste in the intestine are detrimental to health, and that bacteria of the *Bacillus acidophilus* group are beneficial. This theory is the basis for the treatment of intestinal disorders with remedies designed to encourage the development of the acidophilus bacteria and to discourage the protein-decomposing bacteria. Acidophilus milk and other soured milks are prominent among such remedies.

This laboratory has been studying the influence of mineral salts, and of mineral-bearing substances such as kelp, on the ratio between the acidophilus bacteria and the protein-decomposing bacteria in the intestinal tracts of white rats. Colon bacilli are commonly associated with protein-decomposing bacteria and their numbers are used as an indication of protein-decomposing activity. Colon bacilli are responsible for liberating from decomposed proteins the supposedly toxic substances which cause the condition commonly known as autointoxication.

The public is vitamin conscious these days, and much is said and written about the vitamin deficiency of our foods. Sometimes a vitamin-deficiency ailment appears in a person who seems to be getting a satisfactory amount of vitamin in his food. In such cases it has been claimed by some authorities that bacteria in the intestine may destroy vitamins. This laboratory has studied the activities of certain bacteria on vitamin C (ascorbic acid), to furnish information as to bacterial destruction of vitamins.

Detailed reports of the several studies follow.

The Influence of Calcium Salts on the Fecal Flora of Albino Rats. (James E. Fuller and W. B. Esselen, Jr.) This investigation was undertaken in order to observe the effect on the fecal flora of albino rats of calcium carbonate and tri-calcium phosphate when added to a 60 percent lactose diet. The basal diet itself contained adequate amounts of calcium and phosphorus, and the experimental diets contained enough of the respective calcium salts to furnish one percent of added calcium.

Determinations of the numbers of *Lactobacillus acidophilus* and *Escherichia coli* present in the feces of the animals were made at frequent intervals for a period of approximately ten weeks. There was such a marked fluctuation in the fecal bacteria of the individual rats throughout the experimental period that a definite interpretation of the data is difficult to make. However, the addition of one percent of calcium in the form of tri-calcium phosphate had no marked effect on the fecal bacteria of the rats. The rats receiving the calcium carbonate tended to show an increase in the numbers of fecal *Escherichia coli*, but the numbers of *Lactobacillus acidophilus* were not altered.

The Influence of Bacteria on the Oxidation of Ascorbic Acid (Vitamin C). W. B. Esselen, Jr., and James E. Fuller.) The purpose of this study was to investigate the reported destruction of ascorbic acid by certain intestinal bacteria, and to attempt to discover the mechanism of the vitamin's destruction. Pure cultures of bacteria were cultivated in media containing ascorbic acid. It was found that, instead of destroying ascorbic acid, the bacteria employed in this study actually exerted a protective action which varied directly with the suitability of the medium for bacterial growth, and with the numbers of bacteria present. The experimental data suggest that growing bacteria may retard the rate of oxidation of ascorbic acid by a combination of four factors, namely: (1) the formation of un-ionized copper complexes whereby the catalytic action of copper is destroyed, (2) the production of carbon dioxide with the subsequent saturation of the medium with it, (3) the lowering of the oxygen tension of the medium, and (4) the lowering of the oxidation-reduction potential of the medium.

Additional work has been carried on using a miscellaneous group of forty-five different bacteria, many of which may be present in foods. It was found that most of these organisms significantly retarded the oxidation of ascorbic acid, especially when they were grown in a medium containing a readily fermentable carbohydrate. Thus it would appear that bacteria are not of importance in causing a loss of ascorbic acid in foods.

Gum Production by Aerobacter aerogenes. (Guy R. Vitagliano and James E. Fuller.) Certain strains of *Aerobacter aerogenes* produce a great deal of viscous growth in certain media, particularly those containing sugars. Ropy milk may result from the growth of this organism, and it may cause similar ropy fermentations of any sugar-containing substance. The object of this study was to determine factors which would stimulate the organism to produce large quantities of gum, in order that the gum might be more easily studied.

Bacto tryptone and Bacto peptone were more suitable for quantitative gum production than were ammonium salts or aspartic acid. Sucrose was the most suitable carbohydrate, but lactose and dextrose also gave good results. Glycerol and mannitol yielded less satisfactory quantities of gum. Sodium chloride, calcium chloride, magnesium sulfate, and dipotassium phosphate in combination stimulated gum production. This study will be submitted for publication in detail.

Relationship of Onion Juice to Bacterial Growth. (James E. Fuller and Ernest R. Higgins.) In the course of some experiments on dried vegetables a few years ago, it was observed that dried onions either had a very low bacterial content or were entirely sterile. Since that time certain investigators have reported that onion vapors have bactericidal power. In the present study several groups of organisms were tested to determine their ability to grow in the presence of onion juice. *Aerobacter aerogenes* strains were more resistant than were strains of *Escherichia coli*, while *Staphylococcus aureus* and members of the *Bacillus subtilis* group grew only in dilute concentrations of the juice. Salmonella and Pseudomonas strains were quite tolerant to the juice. Onion juice sterilized by steam pressure was much less potent in preventing bacterial growth than was juice sterilized by filtration through a Seitz filter.

Bacteriological Study of Chocolate-Flavored Syrups and Cocoas. (Ralph L. France, with W. S. Mueller.) This study is reported by the Dairy Department.

Laboratory Service. (Ralph L. France.) Following is a list of the types and numbers of examinations made during the past year.

Milk (bacteria counts)	1,071
Ice Cream (bacteria counts)	50
Water	106
Miscellaneous:	
Streptococci	18
Throat Swabs	17
Anaerobes	2
Smears	2
Total	1,266

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Effect of Soil Temperature on Gardenia. (L. H. Jones.) Under the title "Relation of Soil Temperature to Chlorosis of Gardenia," previous work has been published in *Jour. Agr. Research* 57:611-621 (1938). Recent results show that low soil temperatures definitely favor the initiation of reproductive development and that high soil temperatures favor vegetative development. Bud development and blossoming are normal as soil temperature is raised, but abnormal if it is lowered. Bud drop is a sinister threat to successful commercial culture of gardenias. The sudden dropping of buds appears to be closely related to previous conditions rather than to conditions prevalent at the time of falling. Neither an increase nor a decrease in soil temperature prevented well-developed buds from falling from plants that were chlorotic and hard.

Root Temperature Effects in a Nutrient Solution. (L. H. Jones and G. E. O'Brien. Cooperative with Chemistry.) The fact that rate of growth, size of leaf, and healthy green color of the gardenia plant are affected by the root temperature raises the question of what precise factors are involved. Since temperature governs the speed of reaction and is not of itself the reaction, it is of importance to study the effect of temperatures on all known reactions concerned with root activity. For the present, it is deemed advisable to simplify the problem by using nutrient solution culture of plants instead of a complex soil environment for the roots.

Time has been spent in perfecting a technique, in which soybean plants are used. It is now possible to control the temperature of the solution in which the roots are kept. The solution temperatures used are 50°, 70°, and 90° F. Preliminary results indicate that root temperature affects the rate of transpiration and absorption of water. Plants in a nutrient solution at the low temperature wilted, thus definitely showing the depressing effect of low root temperature on absorption of water. At the higher solution temperatures, the rate of change of the pH value of the solution increased, this increase also being attributable to absorption activity. It will be of considerable interest to learn whether there are different temperature levels at which all nutrients may be absorbed and translocated, or whether each element may require a different temperature level.

Soilless Plant Culture. (L. H. Jones.) Considerable time has been given to problems arising from a popular interest in growing plants in water or sand supplied with inorganic nutrient elements. From conferences and correspondence, it was learned that improper use of chemicals and the purchase of wrong chemicals were the causes of most failures. In particular, mistakes were made in obtaining potassium phosphate, which should be monobasic (KH_2PO_4), and iron sulfate, which should be ferrous sulfate (copperas) with the formula ($FeSO_4 . 7H_2O$). Demonstration of methods and technique and the supplying of information have been services rendered in connection with an increasing interest in this subject.

Top and Bottom Watering of Plants in Clay Pots. (L. H. Jones.) Tests show that plants in clay pots on a moist surface should be watered on top. Plants deriving their moisture solely from the moist surface under the pot either died or failed to grow. Plants in clay pots kept on a dry surface and watered on top made mediocre growth, with small leaves and short internodes. The practice of standing potted plants in a pool of water for a short time is effective but risky, as the soil may become waterlogged. Water should never be applied, if the soil is already wet to the touch.

Study of Diseases of Ornamental Herbaceous Plants Caused by Soil-Infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) After sowing small seeds, it is a good practice to water the soil from below by setting the containers into shallow pans of water and removing them as soon as the soil becomes saturated. A soil fungicide may be applied at the same time. Both formaldehyde and pyroligneous acid controlled damping-off and improved germination when applied in this way, but the latter was less effective.

When the soil has been *previously* disinfected by chemicals, however, it may be less safe to water it from below than to water it from above in the usual way. Water generously applied from above may remove some of the chemical from the soil, but this does not happen to the same extent when soil is watered from below.

Undiluted pyroligneous acid, 175 cc. per square foot, worked into the soil before seeding, gave satisfactory control of damping-off and markedly improved germination and final stands of some species, but 200 cc. proved injurious. More use might well be made of pyroligneous acid as a soil disinfectant by those near enough to its points of manufacture to keep down the cost of freight, for of course it contains much more water than does, for example, commercial formaldehyde.

Formic acid dusts containing 8 or 9 cc. of the acid per square foot, worked into soil immediately before seeding, gave fair control of damping-off and improved germination and final stands of some species without injury to growth.

Crucifers were more susceptible to injury by salicylic acid than were most other plants, and it does not now appear that this material can safely be used with them, although there are continued indications that it may have a place in the protection of some other species against damping-off.

Copper oxalate, in soil applications which were safe enough with slowly germinating seeds of some woody plants, was injurious to seeds of herbaceous plants which germinate rapidly.

A paper on work done under this project was published during the year as Massachusetts Agricultural Experiment Station Bulletin 351.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modifications of Environment. (W. L. Doran.) Red copper oxide, applied to the seeds of several species, did not satisfactorily protect them against damping-off. Sulfuric acid, applied at the rate of 10 to 12 gm. per square foot of soil, improved the germination of seven species of Rhododendron.

Untreated softwood cuttings of some species rooted better in a sandy soil, even when it was infested with damping-off fungi, than in clean sand, and received more benefit from growth substances when grown in soil than in sand. However, some species rooted well in sand, and others rooted better in a sand-peat mixture than in soil, whether treated or not. Growth substances did not improve the rooting of leafless hardwood cuttings of deciduous-leaved plants, and generally failed to induce rooting of softwood cuttings of species which did not root at all without treatment. Where growth substances proved beneficial, indolebutyric acid generally produced more improvement than potassium naphthaleneacetate or naphthaleneacetic acid, and the latter seemed more likely to cause injury. Indolebutyric acid was beneficial to more species than was any of the other substances used.

Response of cuttings to growth substances may be affected by both the rooting medium and the time when cuttings are taken. Cuttings sometimes rooted so well and so rapidly without treatment that they rooted no better with it. Although indolebutyric acid hastened the rooting of cuttings of some species when taken on certain dates, it made no difference in the number which ultimately rooted. As more becomes known about the optimum time for taking cuttings of various species and the factors which affect it, there may be less need for treatment with growth substances, but they will continue to be useful when it is necessary to take cuttings at other times.

The rooting of softwood cuttings of a number of species was not improved by potassium permanganate or by sucrose. Treatment of hardwood cuttings of conifers with acetic acid or with formic acid was equally ineffective. A hot water treatment which apparently somewhat hastened the rooting of cuttings of one species was without effect on another.

Chemical Soil Surface Treatments in Hotbeds for Controlling Damping-Off of Early Forcing Vegetables. (W. L. Doran and E. F. Guba, Waltham.) Formaldehyde, diluted so that 1 quart of the solution per square foot supplied from 3 to 5 cc., was applied to the surface of soil after seeding. Pepper and beet were not injured by 5 cc., and 4 cc. was harmless to celery and onion and to some, but not all, ornamentals. Cress was injured by 3 cc., and 4.9 cc. (one teaspoonful) interfered with the germination of the seeds of all crucifers used, but did not hurt lettuce and beet. Germination and final stands of all species not chemically injured were much improved by 3 to 5 cc., and damping-off was well controlled by 3.7 cc. (three-fourths of a teaspoonful). None of these treatments injured growth of anything but crucifers. When the pots or flats of soil were tightly covered with glass or wet paper after treatment, there was a little more injury to the germination of some species than when the soil was not covered.

Vinegar, 215 cc. in 1 quart of water per square foot of soil surface, applied after seeding, did not injure germination of beet, lettuce, or eggplant and prevented most damping-off; but 230 cc. similarly applied was less safe.

Pyroligneous acid, 140 or 160 cc. in 1 quart of water per square foot, applied to soil after seeding, improved germination and final stands of lettuce, pepper, and cress; and 175 cc. markedly improved germination and final stands of tomato and cauliflower without injury to their growth.

The dry chemical seed treatments — red copper oxide, Semesan, and zinc oxide — insure good control of the pre-emergence phase of damping-off, but serious incidence of the disease in the post-emergence phases of growth of the seedlings is frequent.

Solutions of formaldehyde 1:200 to 1:600, acetic acid 1:300 to 1:500, Seidorin 1:800 and 1:1000, and Larvacide 1:800 to 1:1200 were applied, after seeding, to soil in ground beds at the rate of 1 gallon to 5 square feet. Seidorin and Larvacide emulsions, which contain 45 and 70 percent chloropicrin respectively, caused so much discomfort to workers that they may not be considered practical although they showed fungicidal value. Acetic acid 1:400 gave better results than formaldehyde 1:400 with beet, chicory, eggplant, lettuce, pepper, and radish, and equally good results with cabbage and tomato.

Miscellaneous Tests and Experiments. (E. F. Guba and C. J. Gilgut, Waltham.)

1. *Apple Scab Control.* Five brands of wettable sulfur, ranging from 30 to 98.5 percent sulfur and varying from 6-7 microns to 45-50 microns in maximum particle size, were compared on an equivalent sulfur basis determined from Kolofog, a product containing 30 percent sulfur. Delicious and McIntosh varieties were used in the experiment, and the sulfur sprays were applied six times from April 25 to June 2, using about 300 pounds pressure.

All the materials gave good control of scab. In each row of Delicious yielding apples, there was no russeting of the fruit so prevalent throughout the State this season. In marked contrast to the results of the previous season, which showed a significantly superior fungicidal influence of sulfur of small maximum particle size, the different brands of sulfur offered no striking contrasts in the control of scab. All of the foliage of an unsprayed seedling in this orchard, representing the check on the test, was badly scabbed.

2. *Copper Sprays for Cucumber, Muskmelon, and Tomato.* All the commercial brands of copper fungicides were used on an approximately equal copper basis comparable to Bordeaux 4-4-50. Between July 6 and September 4, eight treatments were applied with a power sprayer (pressure 250-300 pounds) and a two-nozzle spray rod. The unsprayed plots of cucumber and melon were badly infested with downy mildew and the yield was significantly reduced. There was no disease in the tomato planting; hence the value of the various fungicides could not be determined for tomatoes. The check plots of tomatoes yielded as well as the best treatment. The merit of these fungicides on the basis of this season's tests is shown in the accompanying table by a numerical rank determined from yield.

Fungicide	Rating of Fungicide on —	
	Cucumber	Muskmelon
Dow Bordow	1	1
Copper Oxychloride A	1	2
Bordeaux 3-3-50	1	4
Bordeaux 4-4-50	1	4
Cupro-K	2	3
Coprote Dust	2	6
Copper Zeolite	3	2
Basi-Cop	4	1
Burgundy 1-1½-50	4	3
Copper Hydro 40	4	4
Bordeaux 2-2-50*	4	5
Cuprocide 54	5	2
Bordeaux 1-1-50*	5	5
Coposil	6	4
Check**	6	6
Border*	7	7

*Average of 2 rows.
**Average of 3 rows.

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.) Since the previous report, leaf mold resistant lines of tomato from hybrids of a previous cross were hybridized a third time with the Waltham Field Station Forcing tomato. The F_2 generation of this last cross, now growing, shows satisfactory qualities for commercial culture. Arrangements have been made with many greenhouse tomato growers for growing this new leaf mold resistant tomato during the 1939 spring cropping season in comparison with their usual varieties, which are susceptible to leaf mold, and as a source of seed for large-scale growing in the critical fall cropping season, should the tomato prove acceptable. The new leaf mold resistant tomato has been named Bay State.

Carnation Blight Caused by Alternaria dianthi S. & H. (E. F. Guba, Waltham.) No results to report.

In cooperation with Prof. H. E. White, Floriculture, the behavior of varieties of carnation to branch rot and wilt caused by the fungus *Fusarium dianthi* Prill. & Delacr., a serious parallel problem, has been noted. Numerous crosses among resistant varieties, and between resistant varieties and Ward, have been made in an effort to combine disease resistance with desirable quality and color.

Diseases of Trees in Massachusetts. (M. A. McKenzie and A. Vincent Osmun.) Field and laboratory studies of tree diseases during 1938 accorded special attention to the condition of elms, particularly whether the Dutch elm disease was present in Massachusetts. Thus far no elms in the State have been found to be affected by the Dutch elm disease, but the progressive spread of infection to a point about ten miles from the southwestern corner of the State is cause for serious alarm. This situation, in connection with the fact that the known insect carriers of the disease are present in the direct path of its advance in New York toward the western part of Massachusetts, creates a serious problem. The importance of timely and adequate action cannot be emphasized too strongly. Fortunately Massachusetts is in a position to profit by the fundamental progress made elsewhere in the operation of protective programs. In spite of the fact that an increased number of diseased trees has been found during the past year in some infested areas, there are in all cases encouraging indications that the eradication program is meeting with success in the face of many obstacles. The disease is now so close to Massachusetts, and the opportunity for its spread within the State so significant, that concerted effort is urgently needed.

During the past four years the Shade Tree Laboratory has received more than 6,700 specimens for diagnosis relative to disease. In 1938, laboratory studies of more than 1,000 specimens, including collections by four field men, were completed by microscopical and cultural methods. During the year 69 diseases of 34 hosts, including 12 diseases of elm, were studied.

Particular attention was given to the study of those elm diseases which are distinguishable from the Dutch elm disease only by cultural methods. Experiments on potted elms inoculated with vascular fungus parasites have been continued in the greenhouse. A manuscript on "Cephalosporium Elm Wilt in Massachusetts" has been prepared, with Miss Eunice M. Johnson, Institutional Fellow in Botany, as senior author. Other publications in connection with the work on shade tree diseases during the year include: "Combat the Elm Disease" and "Diseases of Nursery Plants" in *American Nurseryman;* "Willow Scab" (mimeographed); "Repair of Hurricane Damaged Trees," Extension Circular; and "Dealing with Storm Damage in Central Massachusetts" in *Proceedings Eastern Shade Tree Conference*, New York Botanic Gardens, December 8-9, 1938.

The serious damage to trees during the hurricane of September 21, at which time approximately 100,000,000 trees were destroyed in Massachusetts, created multitudinous problems in shade tree management throughout widespread areas of the State. Evergreens, especially white pines, near the coast were seriously injured both by flooding caused by the abnormally high tides and by salt spray. Weather conditions of the past summer were favorable for a disease known as "needle-blight" of white pines, and the discoloring effect of salt carried by the hurricane materially added to the confusion associated with this disease. The reddish discoloration of new growth is the chief characteristic of the disease.

Other serious problems arising from the hurricane in matters relating to tree diseases and their carrier insects may demand attention during the next growing season. Especially, the danger of a material increase in the bark beetles which carry the causal fungus of the Dutch elm disease must not be overlooked in view of the favorable beetle breeding conditions created by large quantities of stored elm wood from which the bark has not been removed.

DEPARTMENT OF CHEMISTRY

W. S. Ritchie in Charge

Cooperative Analytical Service. (The Department.) Chemical service to outside agencies was not extensive and involved only a comparison of the manganese content of four chick feeds, the determination of copper in two soils, and the analysis of a mineral lick and two brine solutions.

Testing Analytical Methods. (The Department.) The perfection of methods of analysis is an important project and this work has been carried on especially with zinc, since the laboratory has been acting as an associate referee fo zinc, cooperating with the A. O. A. C. The method was reported in the May 1938 issue of the journal of the above organization. This method shows practically complete recovery of zinc between 5 and 25 gammas. For larger amounts of zinc, smaller aliquots are recommended rather than a development of a different procedure. This method was studied with solutions of the ash of various foodstuffs, obtained for other projects, to which had been added known amounts of zinc. While the method seems practical and gives accurate results, it was deemed advisable to study the reaction of solutions of pure salts of various, and possibly interfering, metals with the carbamate and dithizone reagents. Solutions of the following metals (as chlorides) were compared with these reagents singly and (in a few cases) in various combinations: aluminum, antimony, beryllium, bismuth, cadmium, cerium, chromium, cobalt, copper, gold, iron, lead, manganese, mercury, nickel, palladium, platinum, silver, thallium, thorium, tin, uranium, vanadium, zinc, and zirconium. The results obtained confirmed the belief that the proposed method was applicable for most foodstuffs.

A method for the determination of boron by titration using two indicators (methyl red and phenolphthalin) has proved workable but somewhat difficult because of the low boron content of most foods.

The Iron, Copper, Manganese, and Iodine Content of Fruits and Vegetables. (E. B. Holland, C. P. Jones, and W. S. Ritchie.) For some time, evidence has been accumulating in the scientific literature, that the so-called minor elements play a much more important role in nutrition and health than has been heretofore suspected. Perhaps many of the difficulties of both man and animal may be laid to a lack of one or more of these elements. It seemed important, therefore, that the information regarding these elements in fruits, vegetables, and cereal products used for human and animal foods be brought up to date, using the more improved methods of analysis.

Sixty-three samples were added to the several hundred already under inspection. Some of these came from the Waltham Field Station, others from the market gardeners of eastern Massachusetts and were produced under different cultural practices of fertilization and on various types of soil. The samples showed an appreciable range of ash constituents and the more prominent food groups (by proximate analysis).

Other samples were obtained from the Waltham Field Station to determine what, if any, is the residual effect of previous applications of iron, copper, manganese, and iodine. These samples included greenhouse tomatoes and celery.

"Dark Center" in turnips and "cracked" celery have apparently been shown to be the result of a deficiency of boron in the soil though the condition is remedied by small applications. Fertilization experiments conducted at the Waltham Field Station, to determine the location of the boron in the plant and therefore perhaps its function as well as the residual effects, produced 30 samples for this project. At the present time there is some feeling that the residual effects of boron remaining in the soil may be harmful. Three samples of soil have been taken to determine whether or not there is an appreciable accumulation.

The collection of these samples as well as their analysis is practically complete and this information will be available soon and, it is believed, useful.

Lignin and Its Relation to the Absorption of Minerals by Plants. (Emmett Bennett.) In order to determine the effect of the decomposition products of lignin, this substance was mixed with soils of high and low content of organic matter, in the ratio of one to ten by weight, and allowed to decompose. Conductivity and surface tension measurements will be made after changes have had time to occur.

The electrodialysis of lignin in a Mattson cell produced diffusates different in color and odor. The anode diffusate was dark brown in color and had a pleasant odor, while the cathode diffusate was practically colorless and had a fishy odor.

These differences together with positive qualitative tests for lignin in the anode diffusate suggested a partial separation of this material. These observations would seem to indicate that lignin was more soluble than is generally supposed, and that it consisted of some acidic fractions — all of which would give us a better understanding of its chemical nature and its action on the soil.

Precursors of Lignin. Interest in the general chemistry of lignin and its interrelationship with other plant constituents, has come about because of the part this substance plays in the growth, nutrition, and decomposition of farm crops. This investigation was designed to gain a better understanding of the formation of lignin in the plant.

Pectin has been suggested as a possible parent substance, principally because it has been shown that so-called lignified tissues contain relatively large amounts of lignin and hemicelluloses, with only traces of pectin. On the other hand nonlignified tissues contain relatively large amounts of pectin, small amounts of hemicelluloses, and only traces of lignin. A two-year study of the seasonal variations in content of pectin, hemicelluloses, and lignin was conducted with a legume (red clover, *Trifolium pratense*) and a grass (Kentucky blue grass, *Poa pratensis*), taken at successive stages of growth.

Seasonal trends of both plants indicated that the content of pectin was relatively constant, while that of the hemicelluloses and lignin increased. In mature red clover the content of these constituents was of approximately the same general order, while in mature Kentucky blue grass a trace of pectin was associated with twenty-five times as much hemicelluloses and eight times as much lignin. A relationship between these substances was not apparent in either plant. The seasonal variations, however, showed that the same content of lignin in different plants may be associated with variable quantities of pectin, and that the presence of a trace of this substance does not necessarily signify that a transformation has occurred. It seems, therefore, that differences in the proportion of pectin, hemicelluloses, and lignin in different plants are probably due to variations in cell structure rather than to transformation.

The Effect of Storage and Processing on the Carbohydrates of Some Varieties of Edible Onions. (Emmett Bennett.) Onion storage is of vital interest to the grower because it is often accompanied by considerable losses. Before ideal storage conditions can be defined, it is necessary to determine the nature of these losses and ascertain the effect of different storage conditions.

Consistent with this plan "seed" (Yellow Globe Danvers) and "set" (Ebenezer) onions were stored in a warm dry room, in a basement, and in a commercial storage, from October 14 to February 14. These storages will be referred to hereafter as A, B, and C respectively. Storage A represented relatively high temperatures and low relative humidity; C, relatively low temperatures and high relative humidity; and B, conditions intermediate between A and C. Before and after storage representative samples of both "seed" and "set" onions were analyzed to note changes in composition.

The following results were obtained from the crop of 1937. Before storage, "seed" and "set" onions consisted of approximately 11 percent of dry matter, which was principally sugars. Reducing sugars were dominant in the "seed" and sucrose in the "set".

The "seed" in storages A and B had either sprouted or rotted so badly that the shrinkage was not recorded. Those in storage C shrunk 12 percent. No marketable onions were obtained from storage A, while 15 percent were obtained from B and 56 percent from C. The "set" onions from storages A, B, and C shrunk 24, 13, and 6 percent respectively, and yielded 43, 73, and 88 percent of marketable onions. The greater percentage of marketable "set" onions was probably due to their greater maturity. The analyses indicated that approximately one-eighth of the total sugars was lost regardless of storage.

Since a considerable quantity of onions are consumed in boiled form, changes effected by boiling were also determined. This treatment caused a loss of total sugars slightly greater than that recorded in storage.

These data indicate the following:

1. Sucrose is the storage product of the Ebenezer onion.
2. The chief losses in storage were from rotting and sprouting.
3. Relatively low temperatures and high relative humidity retarded the above losses.
4. The different conditions of storage employed caused no significant loss in the content of total sugar in the Ebenezer onion which did not rot or sprout.

Investigations of Some Physical and Chemical Properties of Mosaic Viruses. (Monroe E. Freeman.) Mosaic diseases of plants cause severe losses in many crops of economic importance in Massachusetts. It was recently shown that tobacco mosaic is caused by a virus of protein nature. Additional evidence indicates that many other mosaic diseases are caused by similar agents. Not much is known, however, about their behavior or properties. This study has been undertaken in the expectation that such knowledge may be of assistance in devising methods to control these diseases.

The virus in juice from infected plants remains active, in some cases, for long periods of time; in other cases, for only a few hours. This property, longevity in vitro, is different in different viruses and is used as a means of identification. Why the virus loses its infectious ability under these conditions or why the viruses differ so markedly in this respect is not known. Since oxidation may play a prominent role, a study of this possibility has been undertaken by measuring the effect of acidity and oxidation potential on two viruses of the potato mosaic group. The acidity ranges of stability and inactivation were determined for the viruses of potato rugose mosaic. The two react quite differently and this affords a very simple means of separation. Five acids and two bases gave essentially the same results. Reliable measurements of the oxidation potential of crude juice could be obtained only in a nitrogen atmosphere after several hours; owing, probably, to the reaction of some juice components with atmospheric oxygen. After a partial clarification of the juice, oxidation potentials could be quickly and easily determined. When rugose juice was so treated and adjusted to a low oxidation potential by cysteine, its longevity in vitro was increased.

Chemical Changes in Cooking of Vegetables. (Monroe E. Freeman and W. S. Ritchie.) An important factor of cooking quality of potatoes and consumer preference is the texture of the cooked tuber. Potatoes baked under uniform conditions are mealy or waxy depending on variety and cultural conditions. The cause of these differences in texture is not known. Two theories at least have been proposed but not experimentally verified. This study will attempt to determine the cause of differences in texture, because such knowledge should materially aid efforts to meet consumer demand.

One characteristic of mealy potatoes is the separation of the cells in cooked tissue. Since this may be caused by weakness of the intercellular binding material, one theory suggests that there may be a relation between the pectic materials and texture. The loss of pectin through enzymatic action during the preparation of samples was minimized by steaming and by dipping raw slices in boiling ethanol. However, it was noted that any heat treatment altered the distribution of the pectin fractions. The analysis of 10 lots of potatoes for total pectin, calcium pectate, proto pectin, and water soluble pectins did not reveal any relation between these fractions and texture. Nearly all the pectin was found in the hot water fraction. Therefore, this fraction was, in turn, fractionated under conditions designed to remove only a portion of the total pectin. If the theoretical relation does exist, the mealy potatoes should yield a larger proportion of the total pectin. Ten baked samples and two uncooked samples did not support this idea. On the other hand, eight uncooked samples did. The evidence is not conclusive, but the experience with the eight raw samples seemed to warrant further tests which are now in progress on twelve new samples.

The storage of potatoes at higher temperatures may result in rapid changes in the pectins accompanied by spoilage. The storage of four varieties for four and six months just below 40° F. allowed little, if any, change in pectin and maintained the tubers in good physical condition until late spring. Sugars, however, accumulated to an undesirable extent.

Baked mealy potatoes have a dry crumbly appearance, while waxy potatoes look wet and soggy. The loss of water during baking, however, may be almost the same. This observation has led to the theory that the particles in mealy tissue have absorbed or bound the water naturally present to a greater extent than in the waxy potatoes. The method for determining bound water proposed by Dumanski seemed to be particularly suited for this type of material. Since this is a relatively new method, preliminary tests were necessary and clearly showed that extremely accurate measurements of refractive indices were necessary in order to obtain only a fair degree of accuracy in the final results. When ethanol was used instead of sucrose in this method negative values for bound water resulted. Apparently, the ethanol was more readily absorbed by the potato tissue than the water. Sucrose proved satisfactory after careful standardization of the refractometer. The amount of water bound by one gram of dry potato seemed to be fairly constant over a wide range of sucrose concentrations.

For the purpose of studying changes, if any, due to storage and cooking, peas were preserved by canning and freezing in the fall of 1937. Peas obtained in the pod from the same field producing those which were canned and frozen were shelled and half of them dried at low temperatures without cooking. The other half was cooked and then dried. At intervals of ninety days for three hundred and sixty days, samples of both canned and frozen peas were brought out of storage. Half of each sample was dried at low temperatures while the second half was dried after cooking as indicated above.

Results obtained from the proximate analysis gave only general information regarding these samples. The amounts of moisture, nitrogen, ether soluble material, and crude fiber did not vary a great deal. The percentages of nitrogen were somewhat lower in the canned product, either raw or cooked; but these differences were not to be regarded as really significant. For the purpose of this problem, cooking waters were not included in the work being reported here. Since it is probably a home practice to keep cooking waters this may account for these differences. An unexplained fact is that the ash content of the samples after storage, either in cans or frozen, was higher than in the original sample. This cannot be a difference in the samples as they had the same origin.

The second method of analysis (Horwitt, Cowgill and Mendel) considered soluble nitrogen, insoluble residue and the insoluble ash, using H_2O, N/10 HCl, 0.50 percent Na_2CO_3, N/10 HCl+20 mgs. pepsin, and 0.50 percent Na_2CO_3 +50 mgs. trypsin as solvents. It was interesting to note that in the uncooked samples, either canned or frozen, the first three solvents (H_2O, N/10 HCl, and 0.5 percent Na_2CO_3) gave much higher results than the cooked ones. When the acid and carbonate were used with the enzymes, the nitrogen of the cooked samples was the more soluble (or digestible) in all but five out of eighteen samples. The differences in these five samples were not large enough to be significant.

The residue insoluble in these solvents, as well as the ash insoluble in them, was higher in the cooked than in the raw samples regardless of storage. If solubility means digestibility, this would indicate that a larger amount of the organic and inorganic residue is available in these raw samples.

This study is to be the basis for further work with other kinds of foods.

Changes in Meat Stored in Frozen Condition. (W. S. Ritchie.) The samples originated with feeding trials at Purdue University, in which a standard corn ration (corn and tankage) was fed to hogs and compared with one where the corn was replaced by hominy. Samples were made available as follows:

1. Immediately after slaughtering.
2. After the customary storage for ten days.
3. After being stored frozen for three months.
4. After being stored frozen for six months.
5. After being stored frozen for nine months.

The samples were frozen and stored by the Birds Eye Frosted Foods, of Boston, and sent to this laboratory at intervals of three, six and nine months.

In order to indicate and perhaps evaluate any changes either in their chemical composition or in their nutritive value, the samples were all subjected to the same procedures of chemical analysis, vitamin bio-assays (B_1 and G), and such other determinations as might throw light not only on the value of the product as a food but on any possible changes occurring during the long period of storage.

Lean, raw pork has been found to be a good source of the antineuritic factor, B_1. The control samples, sent to the laboratory immediately after the slaughtering of the animals contained 3.8 international units of B_1 per gram for the corn ration and 5.9 units for the hominy ration. After nine months of storage these values remained practically unchanged (4.0 and 6.0 units respectively).

As a source of vitamin B_2 (G), lean pork seems to have much the same value as lean beef, a fair source. The original samples of the pork contained 2.1 and 1.8 Bourquin-Sherman units per gram for the corn and hominy rations respectively. After six months of storage, the samples had not changed in any significant amount. After nine months, both samples showed an increase in B_2 (G) which, however, cannot be regarded as significant.

The general composition of the samples did not materially change during the long storage, at least if total moisture, ash, nitrogen, and ether extract are the basis of judgment. However, the nitrogen distribution changed in that globulin decreased, while the albumin increased. Globulin in this case was taken as that nitrogenous compound precipitated from a 10 percent NaCl extract of the meat on saturation with NaCl. Albumin was that protein, precipitated by heat and CCl_3COOH (2.5 percent) from the filtrate of the globulin determination.

Applying the technique of Mitchell and his co-workers for determining tenderness, collagen nitrogen showed a decrease of 20 percent in six months, while the elastin showed a similar trend. This would seem to indicate an increase in tenderness with aging (or storage).

Digestibility, as measured either by feeding trials with white rats or by the "in vitro" method of Horwitt, Cowgill, and Mendel, showed no change during the period of storage. These two methods of determining digestibility gave very closely agreeing results.

The nutritive value of the protein or its value for growth promotion in white rats, as expressed in terms of grams gained in weight per gram of protein eaten, remained rather constant throughout the entire period, and agreed very well with figures published by other workers. The average figure for the meat from corn-fed hogs was 2.53 and from the hominy-fed hogs, 2.18.

The Vitamin A Content of Pasture Grasses. (W. S. Ritchie, J. G. Archibald, and Wm. Esselen, Jr. Cooperative with Animal Husbandry.) During the seasons of 1936 and 1937 samples of Rhode Island bent grass, sheep fescue, orchard grass, Kentucky blue grass, timothy, sweet vernal, and red top were assayed for their vitamin A content. The grasses were grown on both fertilized and unfertilized plots.

The work of 1938 repeated that for 1937 in order to complete as nearly as possible the samples from both plots during the same part of the growing season. Almost without exception, the values obtained were higher in 1938 than in 1936 or 1937, regardless of treatment, in some cases as much as two or three hundred percent. There seems to be no reason for this though perhaps it is significant that the rainfall in 1938 from May to October (inc.) was 38.79 inches, while for the same period in 1937 it was 27.17 inches, and in 1936, 20.30 inches.

It was again demonstrated that the vitamin content was higher in grasses from the fertilized plots than in those grown on unfertilized plots. Seasonal variations again did not seem to be as great as those produced by fertilization.

The Nutritive Value of Chocolate Milks. (William Mueller and W. S. Ritchie.) The amount of lead in food has become of such importance that a tolerance has been established. Nine samples of chocolate and cocoa varied from 1.4 to 5.0 p.p.m. in their lead content. These amounts do not seem important since the quantity of chocolate or cocoa used in the preparation of these drinks is not large.

THE CRANBERRY STATION

East Wareham, Massachusetts

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Fire Beetle (*Cryptocephalus incertus* Oliv.). Thirteen cranberry bogs, located in Bourne, Carlisle, Carver, Lakeville, Middleboro, Rochester, Scituate, and

Wareham, were seriously affected by this insect in the summer of 1938, the infested areas comprising about 110 acres in all. The net-counts of the beetles on these bogs ranged from 33 to 875 to 50 sweeps. All the infestations were on the Howes variety, except one on Holliston and one on Early Black. The beetles did not appear in full numbers until the middle of August, even on bogs from which the winter water had been let off early in April.

Derris applied in various ways both in sprays and as dusts failed to effect a good kill of the beetles. Zinc arsenate, 2 pounds to 100 gallons of water, 250 gallons to the acre, failed to give a good kill, possibly because of heavy rains a few hours after the treatment.

As in 1936 and 1937, arsenate of lead was very effective. Evidently 3 pounds of this poison (dry) to 100 gallons of water, 250 gallons to the acre, is about the right spray for this insect. If it is applied in the middle of August (when it will be most effective) and the berries are not picked before October, the lead and arsenic trioxide residues on the fruit should not be above the present legal tolerance (lead, .025 grains; arsenic trioxide, .01 grains per pound of fruit) unless the rainfall in late August and September is definitely below normal.

One grower sprayed some Howes vines for this insect on August 23, 1938, using 6 pounds of dry lead arsenate to 100 gallons of water and applying 250 gallons to the acre. The rainfall was very abundant in September. Most of the sprayed berries were picked on September 26 and two respresentative samples of this fruit were analyzed for residues by the Fertilizer and Feed Control Division of the station at Amherst. Some of the sprayed berries were left unpicked and the bog was completely flooded from September 27 to October 2, inclusive. Two representative samples of these berries, picked as soon as the vines were dry from the flooding and on areas bordering directly and respectively on those from which the previous samples were gathered, were also analyzed for residues. The residues, both lead and arsenic trioxide, on all samples were well below the legal tolerance. It was evident, however, that the water removed over half the lead and two-thirds of the arsenic trioxide. These results confirm those of 1937[1] and show that to flood for several days is a good way to reduce the spray residues on cranberries when arsenate of lead has been used without an adhesive.

	Residue in grains per pound of fruit			
	Before flooding		After flooding	
	Lead	Arsenic trioxide	Lead	Arsenic trioxide
Sample 1	.0105	.00462	.005	.00149
Sample 2	.015	.00561	.006	.00187

Cranberry Weevil (*Anthonomus musculus* Say). The weevils were found on some bogs in numbers giving insect-net counts of 500 to over 1000 per 50 sweeps. They begin to hibernate soon after the middle of August and are hardly to be found in the fall.

The Atlantic Cutworm (*Polia atlantica* Grote). A considerable infestation of this species appeared on a bog in West Wareham and a bog in South Easton in 1938. The winter flowage had been held on these bogs till the last week inMay. Most of the worms reached full growth and began to go into the ground to pupate by the first of August, but a few continued to feed on the cranberry foliage till August 11. The description follows.

Full-grown worm: Length, one and a quarter inches. General color, brown of varying shade above and pale brown or pale greenish below. Head brown, much mottled, with a scattering of rather long hairs. Body with a narrow dark-brown stripe along the middle of the back; a narrow, broken, and somewhat staggered dark-brown stripe along each side of the back; and a narrow white or pale-reddish stripe along each side below the spiracles, some of the spiracles dipping into it. Spiracles brownish white rimmed with black. Some of the worms had pupated by August 3 and most of them had done so by August 10.

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[1] Mass. Agr. Expt. Sta. Bul. 347, p. 43, 1938.

Pupa: Length, ten to eleven sixteenths of an inch. Color rather dark reddish brown. Cremaster bifurcate at the end and with a denticle on each side of its base.

Some of the moths emerged from August 13 to 18; some more emerged in October and early November; and, at the date this is written (December 22), live pupae remain, perhaps to go through the winter.

This insect ranges from the Atlantic coast west to Calgary in Alberta and south into Virginia. Little about the immature stages has been known heretofore.

The worms feed on Roman wormwood, dandelion, and other common weeds and grasses.[2]

Cranberry Fruit Worm (*Mineola vaccinii*). The season's experience with rotenone-bearing sprays in controlling this pest, in both experimental work and commercial practice, sustained previous conclusions well.[3] It was found, however, that 7 pounds of derris powder (4 percent rotenone) and 2 pounds of soap in 100 gallons of water gave as good control as sprays containing more derris. Two applications, both at the rate of 400 gallons an acre, were necessary: one when all but about a third of the bloom was past, and the other ten days later. These two treatments also were an excellent control for the blunt-nosed leafhopper (*Ophiola*) that carries the false blossom disease.

Cube dusts, used when rotenone-bearing sprays are most effective, killed the worms fully as well as the sprays did. One dust containing 2 percent of rotenone and an activator controlled the fruit worm almost completely and also killed the blunt-nosed leafhopper well. As the dusting machine was not working well, a good idea of the proper acre-dosage of this dust was not obtained, but 100 pounds an acre was clearly enough. The application of a dust containing 1 percent of rotenone and an activator was not well timed, but the results suggested that such a dust may prove to be a satisfactory control for the fruit worm. The discovery that this pest can be checked with a dust is gratifying, for cranberry growers have become very generally dust-minded regarding insect treatments.

The rotenone-bearing sprays killed most of the worms as they were entering their first berry near the stem end. The dusts killed most of them while they were hatching from the egg or soon after they hatched and before they left the cup formed by the calyx lobes of the berry.

Impregnated Pyrethrum Dusts.[3] Considerable testing of these materials produced by different manufacturers was done by the station during the season, with good results in most cases; but all of them should have been made somewhat stronger for use against gypsy moth caterpillars. Fully 60 percent of the pyrethrum dusts used by Massachusetts cranberry growers in 1938 were impregnated and they gave very general satisfaction. The high percentage of these dusts used in this, the season of their commercial introduction to the cranberry industry, is explained partly by the fact that the usual high grade pyrethrum powder was hard to obtain in quantity because of the character of the 1937 pyrethrum crop in Japan. The much lower cost of the impregnated material was also an important factor.

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[2] Reported in a letter by W. D. Wylie of the Department of Entomology of Cornell University.

[3] Mass. Agr. Expt. Sta. Bul. 347, p. 43, 1938.

Considerable testing of diluents for impregnated pyrethrum dusts was also done. So far, talc and gypsum, costs and performance both considered, seem preferable to other materials for this purpose.

As June and July were both very rainy on the Cape, many growers had difficulty in finding good weather for treating their pests. In this extremity, some succeeded in controlling the black-headed fireworm well by applying impregnated pyrethrum dusts when the cranberry vines were far from dry and even during light rains.

Prevalence of Cranberry Pests. The relative general abundance of cranberry pests on Cape Cod in the season of 1938 was as follows:

1. Black-headed fireworm (*Rhopobota*) on the whole considerably less prevalent than usual.
2. Fruit worm (*Mineola*) much more abundant than in 1937 in Barnstable County, but generally less prevalent than normal.
3. Weevil (*Anthonomus*) more prevalent than usual, especially on the outer part of the Cape. About as in 1937
4. Fire beetle (*Cryptocephalus*). See above.
5. Gypsy moth not very troublesome in Plymouth County, much less so than in 1937; extremely destructive in much of Barnstable County, very much more so than in 1937.
6. Blunt-nosed leafhopper (*Ophiola*) relatively scarce, probably largely because of general effective treatment.
7. Green spanworm (*Itame sulphurea*) and brown spanworm (*Ematurga*) seem to have become gradually more abundant during the last three years.
8. Armyworm (*Leucania unipuncta*) more prevalent than usual.

Control of Cranberry Bog Weeds. (Chester E. Cross.) About 600 different weed plots ranging in size from 4½ x 6 feet to an acre were treated with various chemicals. Copper sulfate, cyanamid, Elgetol, ferric sulfate, ferrous sulfate, kerosene, Sinox, sodium arsenate, sodium arsenite, sodium bisulfate, sodium chlorate, and sodium chloride were tried as weed killers in various ways. In addition to this strictly experimental work, the results of the weed treatments applied by numerous growers were inspected carefully, especially with regard to the effects of spring and early summer applications. The growers, for example. used over 50,000 gallons of kerosene this year and the results of their work gave a clearer idea of the use and effectiveness of this oil. The main results of all this work were:

1. There should be no walking on or dragging of hose over cranberry vines recently treated with any of the chemicals found useful in killing weeds. The mechanical injury caused by such practices seems to provide entrance to the interior of the cranberry foliage for the toxic materials. Those applying such sprays should always back away from their work as it is done instead of advancing into it.
2. It was thought last year that a solution of sodium chloride, 75 pounds in 100 gallons of water, could be applied to cranberry vines in any stage of growth, be it bud, blossom, or fruit, without causing appreciable injury. This year's work, coupled with adverse weather conditions, proved this idea to be incorrect and led to many tests of the concentrations and quantities of weed-control solutions of copper sulfate, ferrous sulfate, sodium arsenate, sodium chloride, etc. These tests seemed to show that the concentration of these solutions is not particularly responsible for injury to cranberry vines and that the quantity applied is much more important.
3. Cranberry bogs should be rather thoroughly dried out before kerosene is applied to control weeds. Water at the bog surface prevents the penetration of

kerosene into the soil where it can kill weed roots. This does not mean, however, that flooding for protection from frost or for insect control shortly after the kerosene is applied would render the kerosene ineffective, for the penetration of this oil evidently is fairly rapid under favorable conditions, and it is not easily dislodged by water once it has reached weed sheaths or roots. If a bog is flooded the night after kerosene is applied, the weeds affected by the oil die as quickly and completely as they would without the flooding.

4. Treatments with kerosene late in April killed the grass then showing green above ground; but most of the perennial roots had not at that time grown tops, so the grasses came in fairly thickly again later.

The kerosene treatments in May seem to have given especially good results, killing most of the grass and usually causing little vine injury. The normal development of the vines and flower buds is often retarded two weeks by kerosene applied in May, especially in late May. From the 10th to the 14th of May is perhaps generally the best time for this treatment. A few of the tender runners are burned by kerosene late in May, but growers agree that this injury, if coupled with effective weed control, is negligible. Some growers reported complete destruction of crop prospects from kerosene spraying in the middle of May after late-holding of the winter flood. Many and large test plots showed no difference in cropping on untreated areas and areas treated with kerosene in May.

Treating bogs with kerosene in late June or in July is not advisable because of the danger of serious injury to cranberry vines and crop in those months.

Kerosene treatments in August ruin the fruit but do not harm the cranberry vines when carefully applied. Kerosene spraying in August and September has the important advantage of reaching a maximum of weeds, for by that time weeds in general are mostly grown for the season. More work is needed to determine whether kerosene treatments in late summer or early fall reduce the buds for the following year.

5. It was found safe to spray cranberry bogs with copper sulfate up to 30 pounds in 100 gallons of water in May as well as in August. This concentration injured the vines greatly when used in June or July.

The second or third week in August seems the best time to use the copper sulfate solution, 20 pounds in 100 gallons of water, 400 gallons per acre, on nut grass (*Cyperus dentatus*). The nut grass is just as completely killed by this late spraying as by earlier treatments and there is less chance of injury to the vines.

Copper sulfate solution, 25 pounds in 100 gallons of water, 300 gallons per acre, is the best spray found for killing beggar-ticks (*Bidens* spp.) on bogs. It should be applied about the middle of August.

Copper sulfate solution, 20 pounds in 100 gallons of water, 600 gallons per acre, applied late in April or early in May, kills hair-cap moss (*Polytrichum*) completely and seems the best treatment for it so far found.

6. Dusting experiments with sodium arsenite were tried late in August. The results were very encouraging, for all the wild bean (*Apios tuberosa*) foliage was burned off, 70 percent of the poison ivy plants lost their leaves, feather ferns (*Dryopteris*) and *Rubus* were defoliated, and *Panicum agrostoides* was burned to a crisp. Little injury to cranberry vines was caused by either of the two dilutions used: ½ pound sodium arsenite in 9½ pounds gypsum, and 1 pound sodium arsenite in 9 pounds gypsum.

7. A solution of 100 pounds of sodium chloride in 100 gallons of water proved to be a better treatment for wild bean and fireweed (*Erechtites*) than the one of 75 pounds in 100 gallons heretofore advocated.

In the search for some chemical application which will kill all vegetation and so prepare swamp land for setting cranberry vines, it was found that 4 tons of sodium chloride per acre will kill 98 percent of the poison ivy and all other bog plants except species of *Rosa*, which seem very resistant to this treatment. Feather ferns may recover from the treatment a little. Any kind of cheap salt may be used, and it is thought that the winter flood will remove the salt from the soil so that it will not affect the growth of cranberry vines the following year.

Cold Storage of Cranberries. (C. I. Gunness, H. J. Franklin, and C. R. Fellers.) The study of home cold storage of cranberries carried on in 1936 and 1937 was continued, the Departments of Engineering and of Horticultural Manufactures cooperating with the Cranberry Station. See the report of the Department of Engineering.

Hurricane Injury to Cranberry Bogs. (H. J. Franklin.)

Tidal Flooding. The highest tidal wave in Buzzards Bay since 1635 accompanied the hurricane of September 21, 1938. It flooded a number of cranberry bogs near the shore. The following observations on the effects of this flooding were made on September 23, October 20, and December 12, 1938:

1. The vines were killed very generally on limited areas where the water rushed over them with most speed and volume.
2. Vines not picked before the flood came showed no injury from it, even where the salt water remained over a bog for three days.
3. Vines picked several days before the flooding showed little injury.
4. The foliage and terminal buds were killed on well over half of the vines picked only a day or two before the flooding, but the woody parts of the vines generally survived.
5. The water left a very undesirable amount of salt on the berries, but this was largely removed by subsequent rains.
6. As some bog weeds can perhaps be controlled by flooding with ocean water, these notes may help someone wishing to try this. The flood killed back haircap moss completely.

Loss by Wind. Several growers observed that the wind of the hurricane blew some of the berries off the vines on bogs in Wareham. This loss was probably greater and more general than was realized. On a bog of about fifty acres in Greene, R. I., it was estimated that the wind took over 1,000 barrels, more than half the crop. It took all the berries from one section that was estimated to have a crop of 70 barrels an acre before the storm. The berries were found scattered in the woods for a mile from the bog. The wind at the Rhode Island State Airport at Hills Grove, fifteen miles from Greene, reached a velocity of fully 100 miles an hour (estimated) during the storm.

COOPERATIVE CRANBERRY INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station

H. F. Bergman, Senior Pathologist, U. S. D. A., in Charge

Development of Strains of Cranberry Resistant to False Blossom. (H. F. Bergman and W. E. Truran.) During the past season, using the varieties Aviator, Early Black, McFarlin, Paradise Meadow, and Shaw's Success, reciprocal crosses of each variety with each of the other varieties named were made. Reciprocal crosses were made also between Centennial and the varieties Early Black, McFarlin, and Shaw's Success. In addition to these a cross was made between Centennial and Paradise Meadow. Seeds from these crosses will be planted during

January. Seedlings from crosses made in 1936 were set out on the bog during the summer. In October some 435 cuttings of seedlings from crosses made from 1934 to 1936 inclusive were sent to the U. S. Horticultural Station at Beltsville, Maryland, to be rooted and then, in the spring of 1939, to be sent to New Jersey to be tested for resistance to false blossom.

Studies on Flower and Fruit Production. (H. F. Bergman and W. E. Truran.) The number of flowers and fruits formed on uprights from terminal buds of large, medium, and small size was determined on the State Bog on approximately 1000 uprights of each of the three varieties, Early Black, Howes, and McFarlin. In Early Black large terminal buds produced more uprights with five flowers, medium terminal buds more uprights with four flowers, and small terminal buds more uprights with three flowers than with any other number. This held true, in general, in the other two varieties, except that in Howes on section 13 both large and medium terminal buds produced more uprights with five flowers than with any other number. The average percentage of flowers which produced fruit was: Early Black, section 5, 23.8 and section 14, 10.7; Howes, section 7, 14.6 and section 13, 17.2; McFarlin 23.4. These percentages, even the largest, are low; the normal average for any of the three varieties varies from 30 to 35 percent. In Early Black on section 14, in 1933, 45 percent of the flowers produced fruit and only in one year during the last seven has the percentage of flowers which produced fruit been as low as in 1938. The former year was 1935 when the percentage of flowers which produced fruit, in Early Black, varied from 18 to 22. In Howes and McFarlin, in 1935, the percentage was somewhat higher than in Early Black but was still below the normal average. The lowest previous average for Howes was in 1936 on section 13, when only 19 percent of the flowers produced fruit. The very low production of fruit in 1938 is to be attributed in part probably to prolonged rain (7-10 days) during the blossoming period which interfered with pollination, and in part to hot weather during July and August which promoted the development of fungi that caused many of the very young fruits to blast.

Spraying Experiments for Control of Rosebloom. (H. F. Bergman and W. E. Truran.) One application of Bordeaux 5-2-50 at the rate of 150 to 250 gallons per acre gave complete control of rosebloom on three bogs on which tests were made. Rosin fish oil soap, casein, or sodium salts of sulfonated diphenyl compounds as spreaders were equally effective. On plots on the State Bog which had been sprayed for rosebloom control in 1937, the amount of rosebloom in 1938 was very small as compared with the amount on areas not sprayed in 1937.

Spraying Experiments for Fruit Rot Control. (H. F. Bergman and W. E. Truran.) Bordeaux 5-2-50 and red copper oxide (Cuprocide), 2 pounds with 2½ pounds of bentonite to 50 gallons of water, were about equally effective in rot control and were superior to all but one of the spray combinations used this year. These sprays reduced the rot to one-half to one-third of that in the check plots at the time of picking. Also spoilage did not proceed as rapidly during the storage period in berries from plots on which these sprays were used as in those from unsprayed plots, so that at the end of the storage period on December 1 the beneficial effect of spraying was more apparent than at the time the berries were picked. The use of 1 pound of rosin fish oil soap, 1 quart of penetrol, 1 quart of Sunoco spray oil or 2/3 to 1 pound of Areskap or Santomerse in 50 gallons of Bordeaux spray as the spreader made no difference in the control afforded by the Bordeaux. When ½ pound of Areskap was used with Bordeaux, rot control was definitely less effective than when the larger amounts of Areskap were used; and when the amount of Areskap was reduced to 2 ounces to 50 gallons of spray very little control was obtained. Copper hydro 40, on the one bog on which it was used, was only a little less effective than Bordeaux with soap, or than Cuprocide, as judged by the amount of rot present at picking time; but as the berries were held in storage, spoilage proceeded more rapidly in those from plots sprayed with copper hydro 40 than in those plots on which the other sprays had been used. Cuprocide 1 pound to 50 gallons with 1 quart of lethane and 2 quarts of soluble cottonseed oil was much less effective in rot control than the Cuprocide-bentonite spray or than Bordeaux. When the Cuprocide was reduced to ½ pound with the same amounts of other materials in the spray, there was at least as much rot in the berries from sprayed plots as in the berries from the checks. One pound of Cuprocide 54 with 1 quart of soluble cottonseed oil in 50 gallons of water had very little effect on rot control. Fungatox, a prepared liquid red copper oxide, used at the rate either of 1 pint or of 1 quart to 50 gallons of water, not only failed to control rot but in most instances increased the amount of rot as compared with that in check plots.

The best control of fruit rots by any spray used was obtained with a modified Bordeaux which contained some zinc arsenite. Four different formulas (two of the four also with monocalcium arsenite) were tested on a few small plots on the State Bog. Of the four, a 5-3-50 Bordeaux to which 1 pound of zinc arsenite was added reduced the rot to about one-half of that obtained by the use of regular 5-2-50 Bordeaux. This formula appears to be worthy of further tests.

Leaf samples were collected from sprayed plots, after each of two applications given, to determine the distribution and total content of the spray residue. On all plots which had been sprayed with Bordeaux or with the Cuprocide-bentonite mixture the copper content of the spray residue varied between 0.5 and 0.8 mg. per gram of leaf sample. Variations within this range appeared to have no effect on rot control. On plots on which there had been little or no rot control the total copper content of the spray residue was very low, usually 0.1 mg. or less per gram of leaf sample, and tests for distribution also showed little or no copper present.

Blueberry Disease Investigations. (H. F. Bergman.) In a preliminary experiment on the control of the mummy berry disease (*Sclerotinia*) of blueberries two applications of Bordeaux 5-2-50, one just before the flowers opened and the other after the petals had fallen from most of the flowers, appeared to be effective as hardly any "mummies" were found after spraying. More than the usual proportion of mummied berries were produced on unsprayed bushes near by.

Observations made in the fall on the susceptibility of blueberry varieties to powdery mildew showed that Pioneer is clearly the most susceptible. Cabot, Wareham and Rubel follow in the order named. Katherine and Harding appear to be the most resistant of all varieties now grown in Massachusetts. Concord and Jersey appear to be somewhat less susceptible than Rubel and somewhat more susceptible than Rancocas and Stanley, which approach Harding and Katherine in resistance.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Improving the Flavor and Keeping Properties of Milk and Some of Its Products. (W. S. Mueller and M. J. Mack.) This investigation has been continued from the previous year by studying the antioxidative and other properties of various cereal flours: Oat (finely milled), whole oat, corn (maize), bleached wheat, whole wheat, barley, rye, and rice. Studies with water solutions of these various flours showed that the pH ranged from 5.82 to 6.02; the titratable acidity, from .2 cc. to .85 c.c. of .1N NaOH when using a 25 c.c. sample; and the solubility, from 3.6 to 62.5 percent.

The antioxidative properties of the various cereal flours were determined by adding .25 percent of flour to whole milk known to be susceptible to oxidation. Oat flour, whole oat flour, and corn flour were about equally effective in retarding oxidized flavors, while the other cereal flours possessed but little antioxidative value. The cereal flours, in the concentration used, had no significant effect on the viscosity, pH, and titratable acidity of the milk. Whole oat flour and corn flour imparted a stronger flour taste than did oat flour.

Because of the hulls present, whole oat flour cannot be used as an antioxidant for dairy products. This leaves only oat flour and corn flour as possible antioxidants since the other flours possess but little antioxidative value.

Corn flour and oat flour were compared as antioxidants for ice cream, using .5 percent by weight. The data thus far obtained indicate that corn flour is practically equal to oat flour for this purpose. Corn flour increased the viscosity of the mix more than oat flour, and retarded overrun somewhat. It is probable that this slight reduction in overrun can be corrected by adding less corn flour without loss of protection against oxidized off-flavors.

Various parchment papers treated with oat flour have been tested for wrapping butter. The butter was stored at temperatures of 38° and 0° F. In most cases the treated parchment paper delayed slightly the development of oxidized flavors at the surface of the butter. This was more pronounced at storage temperatures of 38° than at 0°.

Paper milk bottles and ice cream cartons treated with oat flour have been compared with the corresponding untreated materials for use with dairy products, and appear to have some value in delaying the onset of oxidized flavors. Further data are necessary before conclusions can be drawn from this phase of the work.

The Effect of Chocolate-Flavored Syrups on Some of the Properties of Chocolate Milk. (W. S. Mueller.) The effect of twelve commercial chocolate-flavored syrups on the following properties of chocolate milk have been studied: viscosity, sedimentation, cream layer, pH, and curd tension.

The syrups varied considerably in their ability to affect the viscosity of the chocolate milk. Some of the syrups almost doubled the viscosity of the milk while others increased it only slightly. The suspending agent was found to be chiefly responsible for the increase in viscosity.

Sedimentation in chocolate milk is undesirable because it detracts from the appearance of the product and also causes inconvenience in serving. After 24 hours, 25 c.c. portions of the various chocolate milks in test tubes showed sedimentation varying from none to 2 c.c. The absence of sedimentation was due to a suspending agent in the syrup in some cases; in others it was due to the absence of cocoa fiber in the syrup.

After 24 hours, 25 c.c. portions of the various chocolate milks in test tubes showed a cream layer varying from none up to 2.5 c.c. The undesirability of a cream layer depends largely upon the kind of chocolate syrup used and also individual preference. If the cocoa fiber has not been removed from the syrup, then a cream line is extremely undesirable because the cream layer will have an uneven dark or dirty-looking color which is sometimes mistaken for curd lumps. If a cocoa fiber free syrup is used, then the cream layer will have a more creamy color which has the advantage of indicating to the consumer the approximate amount of butter fat in the chocolate milk.

Although the pH of the various syrups varied from 5.0 to 6.5, yet the pH of the chocolate milk remained nearly constant, varying only from 6.3 to 6.6.

All of the chocolate-flavored syrups lowered the curd tension of the plain milk from the original 42 grams — to 0 in some cases, but only to 25 grams in others. The lower curd tension of chocolate milk is not due entirely to the dilution of the milk with the syrup. The suspending agent (sodium alginate) was found to be more effective in lowering the curd tension than either the sugar or the cocoa.

The effect of the acidity of milk on the appearance and consistency of chocolate milk made from a specific chocolate-flavored syrup has been studied. Increasing the acidity of milk from .16 percent to .24 percent decreased the viscosity and increased the separation in chocolate milk.

Some of the chocolate-flavored syrups mixed with milk more easily than others, but none were objectionable in this respect.

Factors to be Considered in Selecting Chocolate-Flavored Milk. (W. S. Mueller.) The results of the chocolate milk study are given in a paper, "Factors to be considered in selecting chocolate-flavored milk," which was presented at the recent Conference of Food Service Directors at Rochester, New York, and will be published in the Journal of Dairy Science. A good chocolate milk should have the following properties:

1. A flavor which appeals to the majority of steady consumers.
2. A low bacteria count. (The maximum bacteria count should comply with state and municipal laws for the grade of plain milk which is used as a base in the chocolate milk.)
3. No excessive viscosity. (Viscosity should be kept as low as possible without obtaining sedimentation.)
4. No sedimentation.
5. A cream layer, if any, which is cream colored and not dark or mottled.
6. A minimum amount of sugar, which is approximately 5 percent.
7. An acidity of the milk used as a base for the chocolate milk which is not higher than .2 percent and preferably lower.
8. A total fat content of at least the butter fat required by the state standards for plain whole milk. Total fat includes the butter fat in the milk and the cocoa fat normally found in the chocolate flavoring material. (The term "chocolate milk" in this instance refers to the product made from a whole-milk base and does not include "chocolate-flavored dairy drinks." This latter term is commonly understood to mean, in many localities, a chocolate-flavored drink made from skimmed or partly skimmed milk.)
9. A cocoa content not high enough to decrease the digestibility of the milk. Approximately 1 percent of cocoa by weight, in the finished product, does not adversely affect digestibility and is enough to flavor the product.

Nutritive Value of a Chocolate-Flavored Syrup Containing Yeast. (W. S. Mueller and L. D. Lipman.) Chocolate-flavored syrups and cocoa powders supplemented with various vitamins have been introduced commercially. One of these syrups containing yeast was assayed for both vitamins B and G, and was found to contain not less than 10 international units of B and not less than 11 Bourquin-Sherman units of G per fluid ounce.

The total nutritive value of chocolate milk (made up of 1 part of this syrup and 11 parts of milk testing 4 percent butter fat) and of the plain milk was measured by exclusive feeding of the milks, supplemented with minerals, to albino rats. The animals receiving the chocolate milk made considerably greater gains in weight than animals on the plain milk diet. It was calculated that 100 grams of the plain milk contained approximately 70 calories, compared with approximately 90 calories per 100 grams of the chocolate milk. The growth curves reflect these differences in caloric value of chocolate milk and plain milk.

The Digestibility of Chocolate-Flavored Milk in Vitro. (W. S. Mueller and L. D. Lipman.) The purpose of this study was to check, if possible, the results of the animal feeding experiments. Digestion experiments have been made with plain milk and chocolate milk containing 1, 2½, and 4 percent Dutch process cocoa. Digestion was carried out with artificial gastric juice, in a rotating machine set in an incubator at 37° C., in order that digestion might go on under conditions somewhat approaching those of the stomach. Samples were taken out before digestion and after digesting for 2, 4, and 6 hours, and were then analyzed for non-protein nitrogen by the Macro-Kjeldahl method. As digestion progresses, the proteins are broken down to non-protein nitrogen, a process by which the proteins are so changed as to make assimilation possible. Therefore, an increase in non-protein nitrogen indicates progress of digestion. By this method it was found that digestion made the greatest progress during the first two hours and increased only slightly from then on up to six hours.

Preliminary results show that cocoa retards the digestion of the milk proteins and this retardation is increased as the percentage of cocoa is increased from 1 to 4 percent in the milk.

Bacteriological Study of Chocolate-Flavored Syrups and Cocoas. (R. L. France (Bacteriology) and W. S. Mueller.) The purpose of this investigation is to find out to what extent chocolate-flavored syrups and cocoa powders are responsible for microorganic contamination in chocolate milk.

Twenty chocolate-flavored syrups and 20 cocoa powders have been analyzed for total number and kind of microorganisms present. The plate count ranged from 20 to 200,000 microorganisms per gram in the chocolate syrups and 1,000 to 55,000 microorganisms per gram in the cocoa powders. No coliform bacteria or organisms producing hemolysis were found, which indicates the absence of pathogenic organisms in the syrups and cocoas examined. Results to date indicate that where the chocolate-flavored syrups are added to cold milk, some of the syrups examined would seriously increase the bacterial content of the chocolate milk. High bacterial counts in cocoa powders are not as serious as in chocolate-flavored syrups, because the cocoa is heated during the preparation of the syrup and also because less powder is used than syrup.

The investigation will be continued until sufficient samples have been analyzed to draw more definite conclusions.

The Effect of Aging Treatments on Gelatin and Other Ice Cream Stabilizers. (W. S. Mueller.) Various stabilizers have been subjected to the high initial aging temperature treatment described for gelatin in last year's report. These substances do not exhibit the differences in physical properties that were noted with gelatin. Further studies are being made with other stabilizers.

The effect of agitation during the high initial aging temperature period was studied. The following treatments had a marked effect on the viscosity of a 1 percent gelatin solution.

	Viscosity °M
Aging 24 hrs. at 38° F., without agitation	134.7
Aging 6 hrs. at 68° F. + 18 hrs. at 38° F., without agitation	304.5
Aging 6 hrs. at 68° F. with agitation + 18 hrs. at 38° F. without agitation	382.0

These results indicate that the efficiency of gelatin in ice cream could be further increased by agitating the mix during the initial high aging temperature period. The effect of the amount of agitation during this period on various properties of gelatin is being studied.

Some Factors Affecting the Properties of Whipped Cream. (W. S. Mueller.) The effect of agitation of the cream after pasteurization on the whipping properties of the cream is being studied. The results seem to indicate that preliminary agitation of the cream immediately after pasteurization does not improve its whipping properties. A preliminary agitation period of one-half minute, at 70°, 85°, or 100° F., decreased the rate of whipping and slightly decreased the overrun, but did not affect the maximum stiffness and the amount of serum drainage from the whipped cream.

Changes that Occur in the Storage of Frozen Sweet Cream. (H. G. Lindquist.) A few batches of cream, to which small amounts of salts (sodium citrate and disodium phosphate) were added, were frozen and stored. The stored frozen cream, on thawing and heating, oiled off badly, and no beneficial results from the addition of salts were noted. The project will be continued, adding salts and sodium alginate before freezing the cream.

The Use of Egg Solids in Ice Cream. (M. J. Mack.) Egg solids in some form are frequently used in ice cream, and many states specify a minimum amount of egg yolk solids which must be present in ice cream custards.

Either fresh, frozen, or dehydrated egg yolk may be used. One of the principal reasons for using egg yolk in ice cream is to increase the whipping ability and thus decrease the freezing time for ice cream when frozen in batch freezers. Egg yolk has other advantages in ice cream: it affects the flavor and color of the product, increases the stability, and improves the melting appearance of the ice cream.

A number of companies have offered for sale dehydrated egg yolk mixed or "blended" with other solids, such as egg albumen, milk solids, and sugar. The claim is made that these "blends" are superior to the plain dehydrated yolk. The data collected thus far indicate, however, that the blended yolk may be inferior to the powdered egg yolks even to a greater extent than might be expected from the dilution effect produced by the admixture of other solids to the egg yolk. Some blended products appear to affect the rate of whipping very little and to affect adversely the melting appearance of the finished ice cream. Users of blended egg yolk powders have unknowingly failed to comply with State regulations for ice cream custards because of the lower egg solids content of such products.

Factors Affecting the Melting Appearance of Ice Cream. (M. J. Mack.) Ice creams frequently fail to melt to a smooth, creamy liquid, and the consumer may therefore assume that the product is of poor sanitary quality or that it has been adulterated. Invariably the product is entirely suitable for consumption; the unsatisfactory melting appearance is the result of some factor which has no adverse effect on the other properties of ice cream.

Defects which often appear in the melting appearance of ice cream are (1) failure to melt, (2) a "curdy" or "feathery" appearance, and (3) exudation of milk serum from the product. Previous research has shown that factors which affect adversely the stability of the casein in ice cream also cause the melting appearance to be undesirable. In this investigation a number of factors have been found to affect the melting appearance which have little or no effect on the stability of the casein in the product.

The composition of ice cream has much to do with the melting appearance. Variations in the butter fat content as well as in the amount of serum solids, sugar, stabilizer, and egg solids all affect the melting characteristics of the product. The stabilizer used is of significance in this respect as is the homogenization pressure, pasteurization temperature, and rate of freezing. The purpose of this investigation is to establish the effect of each of the above factors on the melting appearance of ice cream so that more satisfactory control of this property of the product can be realized.

Sodium Alginate as a Stabilizer for Ice Cream. (M. J. Mack.) In the two previous annual reports, the results secured with sodium alginate as a stabilizer have been discussed. The product proved to be satisfactory and superior in several respects to other stabilizers now in use. The main disadvantage of the product was its lack of solubility at temperatures lower than 160° F. This project is being continued with a study of alginates prepared in different ways with the hope of developing a product completely soluble at somewhat lower temperatures than those now employed.

The Stability of the Fat Emulsion of Cream. (M. J. Mack.) This project has been discussed in some detail in recent reports of this station. Several factors have been discussed which account for the separation of oil droplets from cream when used in hot coffee. This defect can be prevented by the homogenization of coffee cream at 300 to 500 pounds pressure. Such treatment, however, changes some of the characteristics of the cream. This project is being continued with the purpose of studying the fat emulsion in cream and other dairy products.

A Study of the Possibilities of Milk, Cream, Cheese, and Plastic Cream in the Development of New Dairy Products. (J. H. Frandsen and Myer Glickstein.) Work on this project is nearing completion. During the year many experiments have been made in the development of new products, some in combination with honey, fruits, cheese, and flavors from other sources. In addition to the now successful combination of sweet fruits, sub-acid fruits, candies, nuts, and certain aromatic ripened cheeses with bases such as plastic cream and cream cheese, as mentioned in the last annual report, attention during the year has been given to the possibilities of spices in dairy spreads.

Especially manufactured cream of spices have been used as new flavor substances in cheese spreads. In these experiments pure soluble extracts of these natural spices were used. This makes for a much more sanitary product than is possible when the spices are used in their original form. Preliminary experiments here indicated that original natural spices are often more or less impure, containing dirt, grit, hairs, insect fragments, etc.

A group of consumers was selected at random and asked to pass judgment on various spiced products. Information thus obtained has aided in the development of a number of new dairy spreads in which spices play an important part.

Utilization of Whey By-Products. (J. H. Frandsen and Myer Glickstein.) Within the past few years, attention has been given to the manufacture of food and industrial products from dairy waste material, particularly whey, the by-product of cheese manufacture. Work along this line is now in progress. Already successful methods for the manufacture of whey honey, whey champagne, and whey candies have been developed.

It has been found that fermented cottage cheese whey can be used to make a whey syrup or honey having the color, viscosity, general appearance, and somewhat the general chemical composition of bees' honey or maple syrup. The flavor is pleasing and characteristic of lactic acid fermentation as found in buttermilk.

By the introduction of the proper strains of yeast and various fruit flavors to especially prepared whey, a product has been obtained which gives some promise of the development of a new pleasing, sparkling beverage.

Candies made from whey and milk powder have opened still further possibilities. Several formulas have been developed for the manufacture of cream candies, chocolate covered centers, and caramels. According to consumer reaction, such candies made from whey, together with liberal amounts of milk powder, offer some prospect for developing a new market for dairy by-products.

A Study of the Efficiency of the DeLaval Multipurpose Separator. (J. H. Frandsen, L. D. Lipman, and Myer Glickstein.) In an effort to determine the suitability and practicability of mechanical standardization of milk, several experiments have been conducted with the DeLaval Multipurpose Separator. Results to date indicate that standardization reduces the amount of visible sediment in milk; in general, standardization increases fat and total solids and decreases specific gravity, has little effect upon bacteria count, and has little or no effect upon curd tension. Standardized milk tends to have a better flavor than milk of the same age not standardized. Standardization with a mechanical standardizer is more practical and economical than standardization by siphoning or foremilking.

DEPARTMENT OF ECONOMICS

Alexander E. Cance in Charge

Land-Use Problems in Massachusetts in Relation to a Balanced Program of Land Utilization. (David Rozman.) The work of this project has progressed along the lines of land classification and the determination of the adjustments essential to a balanced program of land utilization. This work has been carried out primarily with a view to providing a basis for and supplementing the activities of the agencies of the United States Department of Agriculture and other Federal and State organizations engaged in bringing about the necessary practical adjustments in land utilization. Because of the variety of soil, topography and social factors even over small areas in Massachusetts, the planning for individual communities can not be adequately promoted unless it is based on a detailed knowledge of a particular locality. With this in mind, under this project the examination of land-use problems was made in a number of Massachusetts communities on the basis of a land-use survey carried out in cooperation with the State Planning Board. In 26 towns covering both eastern and western sections of the State a preliminary analysis was made with due consideration to physical factors such as soil classification, topography, land cover, existing roads, and rural buildings. This was coupled with the examination of social factors, especially as expressed by the trend of population and the development of industries, land values, and real estate taxation.

The preliminary results indicate that the most fruitful developments in effecting adjustments in rural communities will be brought about by two major lines of action. The first is concerned with the prevention and elimination of isolated settlements in rural areas, where excessive costs of maintaining roads, schools, and other social services place a heavy burden of taxation on agricultural land. Secondly, in communities where considerable areas are not at the present time under any form of intensive utilization and where the analysis of physical and social factors does not indicate the possibility of such development the major point of attack should be along conservation lines with scientific reforestation, recreational facilities, and wild life refuges.

The most important application of the material and analyses obtained under this land-use project will be in the work of the State Land Use Committee, recently organized under the leadership of the United States Department of Agriculture, composed of representatives of all Federal and State agricultural agencies engaged in the program of the conservation of human and natural resources in the rural areas of Massachusetts.

DEPARTMENT OF ENGINEERING

C. I. Gunness in Charge

Cranberry Storage Investigation. (C. I. Gunness, H. J. Franklin, and C. R. Fellers.) A fairly complete report on two years' work on the storage of cranberries was made in the 1937 annual report. It indicated that berries kept at 35° showed the smallest storage loss but that berries would color better at 45° with only slightly greater loss than at 35°.

The tests made during the 1938 season checked the results obtained in 1936 and 1937. Berries were held in refrigerated rooms at 35°, 45°, 55°, and 60° and in one common storage. Berries were held at 55° and 60° in order to see whether a difference of 5° in temperature would have any appreciable effect on storage loss. The temperature of 60° is approximately that obtained in common storage. Early Blacks showed a 2 percent greater storage loss when kept at 60° than when kept at 55°, and Howes had a 5 percent greater loss at the higher temperature. This indicates that many growers may be able to reduce losses in common storage by making some effort to obtain lower temperatures in the storage. The first and most obvious step is to provide good ventilation to cool the berries as they come from the bog. The building of large, close stacks of warm berries within the storage should be avoided. Good circulation of night air, either by natural draft or by means of fans, is very desirable. In some cases it may be worth while to insulate the storage to help hold the low temperature obtained during the night.

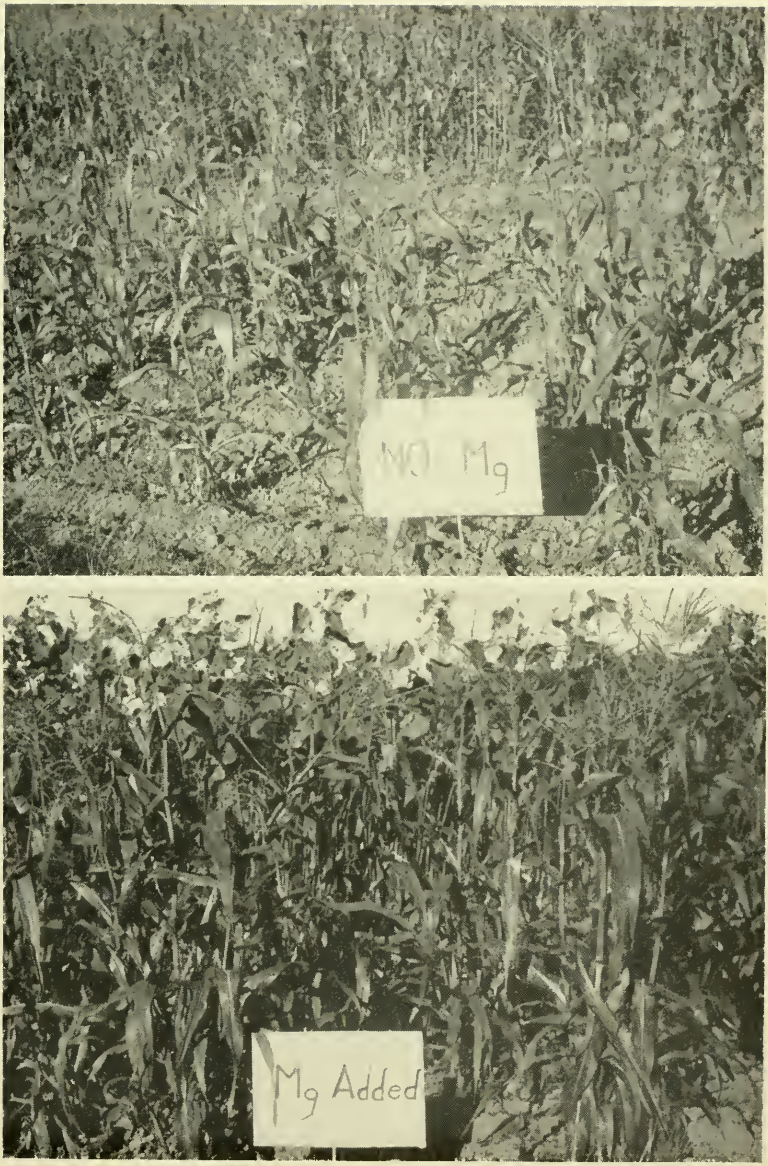
The 1936 and 1937 trials indicated that berries colored better at 45° and 50° than at 35° or 40° or at the temperatures in common storages. In the 1938 trials it was found that berries colored better at 45° than at 35° or at the higher temperatures of 55° and 60°. In an effort to obtain good coloring with minimum storage loss, one lot of berries was stored at 45° for a short period and then transferred to 35°. The storage loss was slightly greater than when berries were stored continuously at 35° and lower than when they were stored continuously at 45°, and the development of color was almost as good as for berries kept continuously at 45°. The practice of holding the storage at 45° during filling and for a period thereafter gives promise of being good management in that it calls for less refrigeration capacity than if the storage is kept at 35° from the time the berries are picked.

Frost Protection on Cranberry Bogs. (C. I. Gunness.) An experimental plant for studying frost protection was installed at the Cranberry Experiment Station in the spring of 1938. It consists of an aeroplane propeller driven by an 8-cylinder automobile motor. The propeller is mounted on one side of the bog and draws relatively warm air from the high land surrounding the bog and drives it out over the bog, displacing the cold air surrounding the vines.

The purpose of the experiment is to determine the amount of temperature inversion above the bog, the rise in temperature which can be produced on the bog with a given temperature inversion, and the area which can be protected with a single unit.

Only two runs were made in the spring of 1938. The results obtained showed promise for this form of protection, but insufficient work was done to warrant any conclusions as to its effectiveness. The work will be continued next season.

Tobacco Seed Cleaner. (C. I. Gunness.) A tobacco seed cleaner was made in the spring of 1938 in cooperation with the State Seed Laboratory. This machine operates on the principle that if tobacco seed is allowed to drop into a horizontal blast of air, the light seed and chaff will be carried farther than the heavy seed.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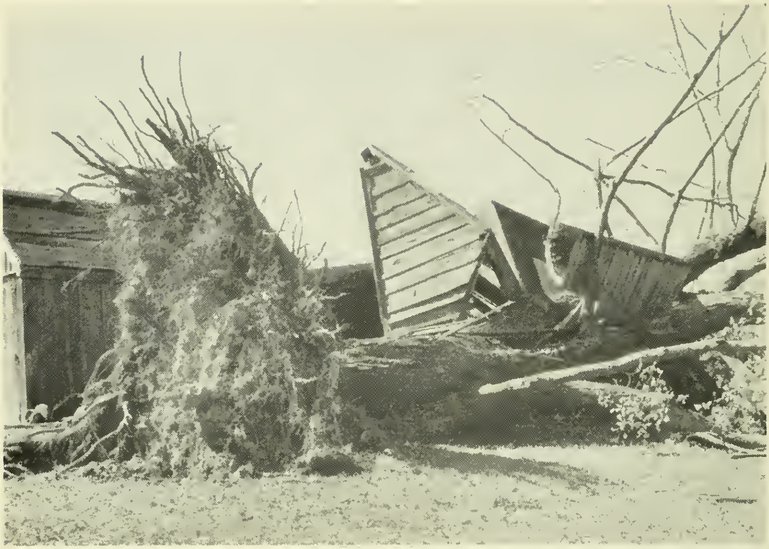
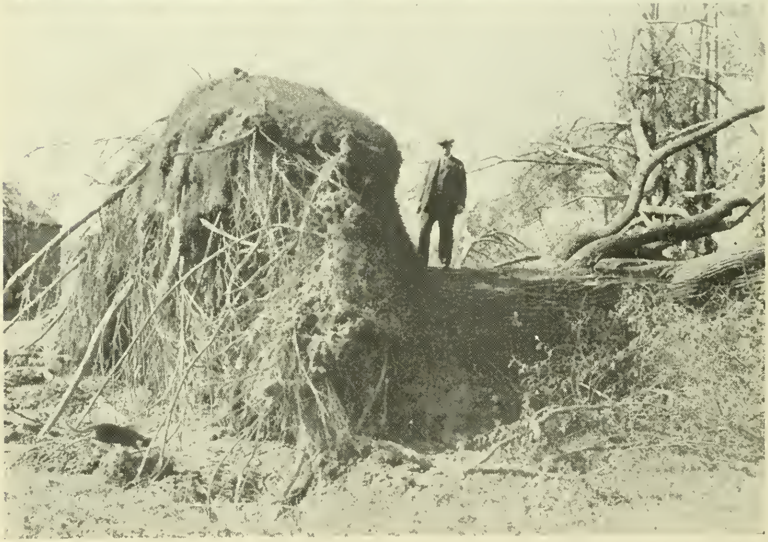
Mg Added

The Effect of Application of Magnesium to Soil Planted to Sweet Corn. (Page 13)

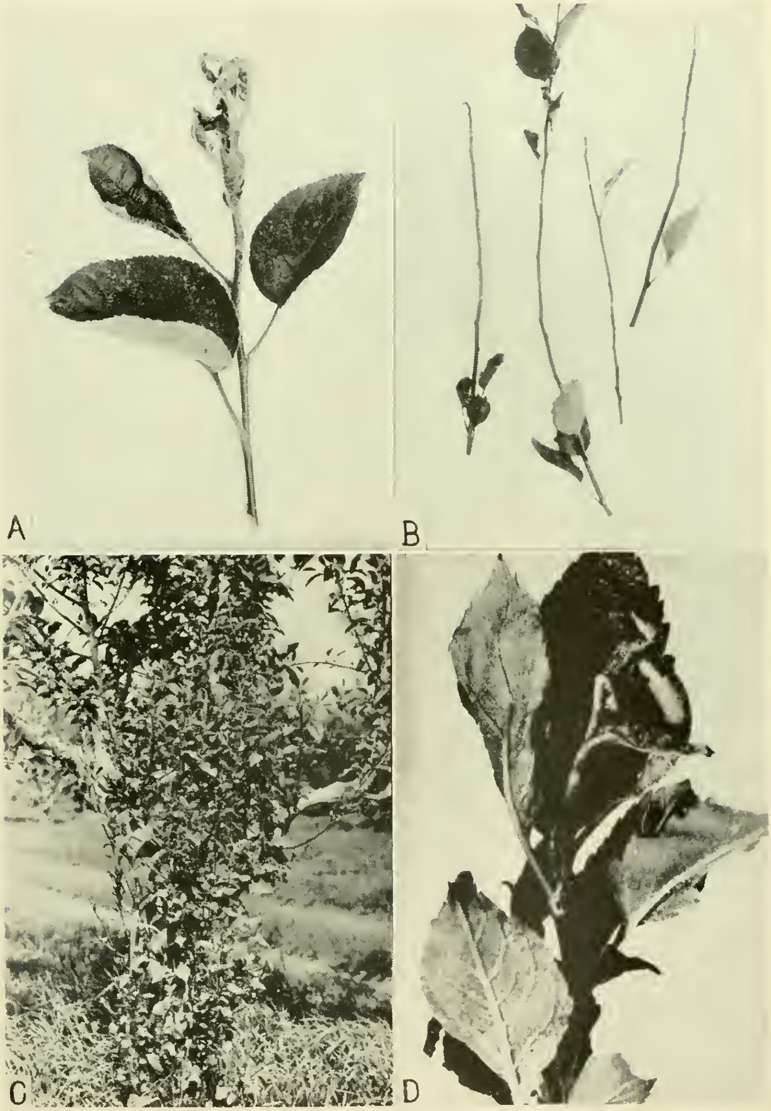




Destruction of Shade Trees by the Hurricane of September 21, 1938. (Page 32)

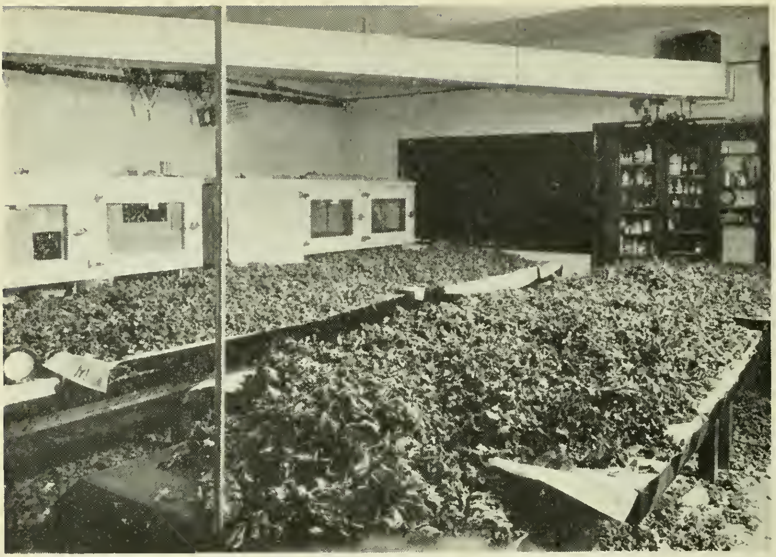
Above: A huge sugar maple in Leverett, blown down with resultant damage to farm buildings.

Below: This American elm in Leverett was one of the largest in Massachusetts, measuring 108 feet in height and 7½ feet in diameter and 23 feet in circumference at 11½ feet above the base. It was free from any evidence of decay and a beautifully typical specimen of the species.



The Apple Leaf Curling Midge, Dasyneura mali Kieffer. (Page 56)

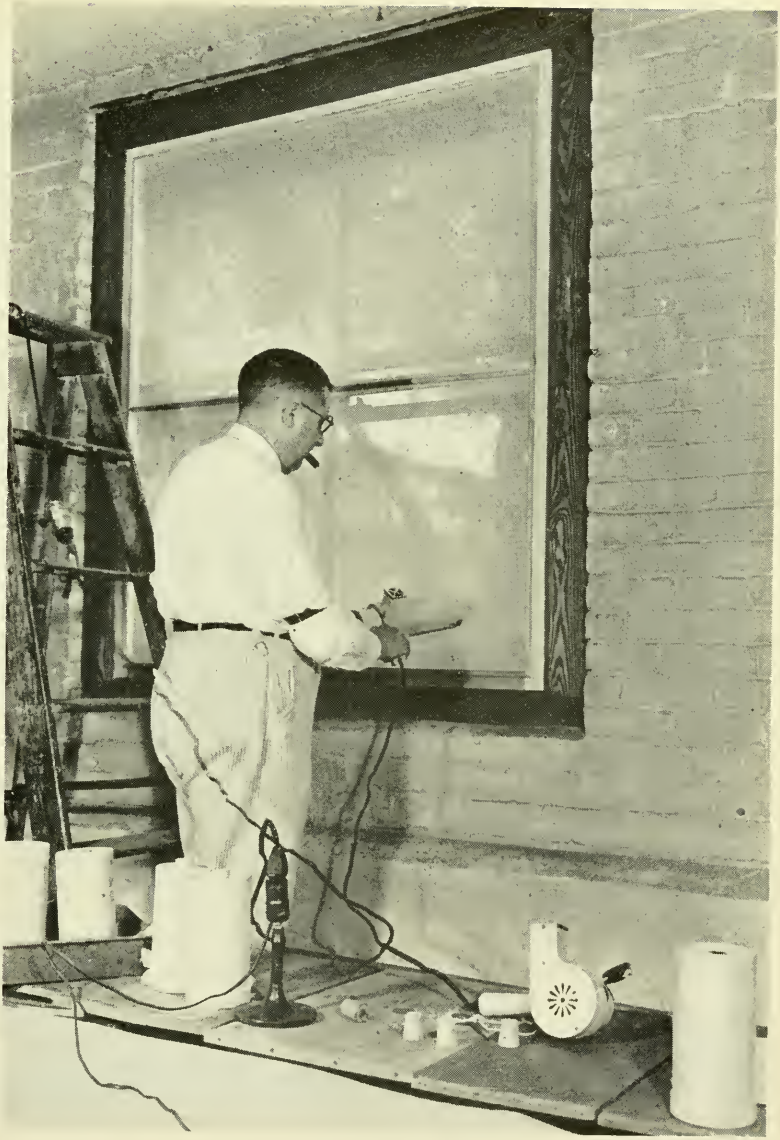
A. Typical infested apple twig.
B. Water sprouts defoliated by D. mali.
C. A heavily infested cluster of water sprouts.
D. Terminal leaves curved by D. mali.



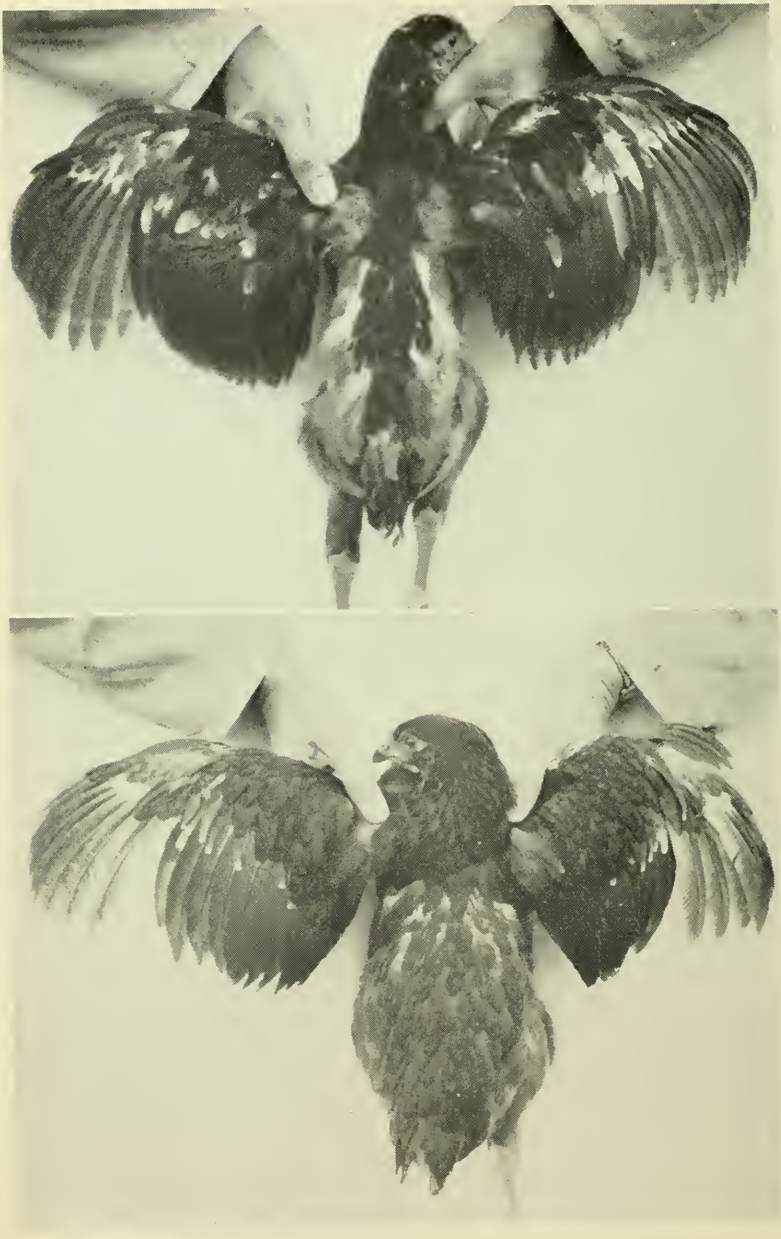
Breeding material from which the parasites were secured for liberation in Massachusetts peach orchards.

More than 150,000 strawberry leaves infested by parasitized larvae of the strawberry leaf roller, an alternate host of Macrocentrus, were collected in New Jersey and shipped to the laboratory at Amherst. The parasites emerged from these leaf roller larvae. It was necessary to keep this material at moderate temperature and high humidity until parasite emergence was completed, in order to prevent premature death of the leaf roller larvae and to insure maximum emergence of Macrocentrus.

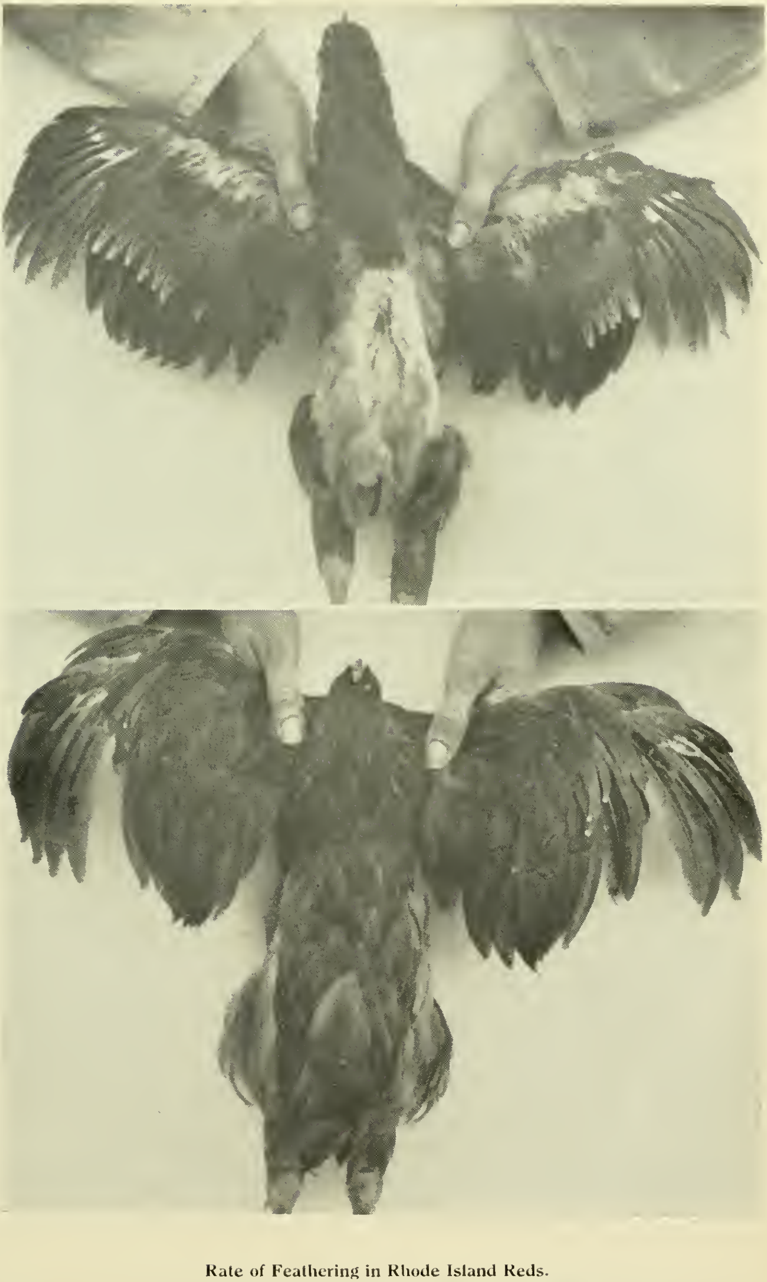
Upon emergence the parasites, attracted by the light, clustered upon the screen at the only undarkened window in the breeding room. They were drawn off the screen by the suction of electric motors into cardboard cartons and were stored in a cooling room to keep them inactive and in dormant condition until taken into the peach orchards and released.



Equipment and method of collecting parasites.



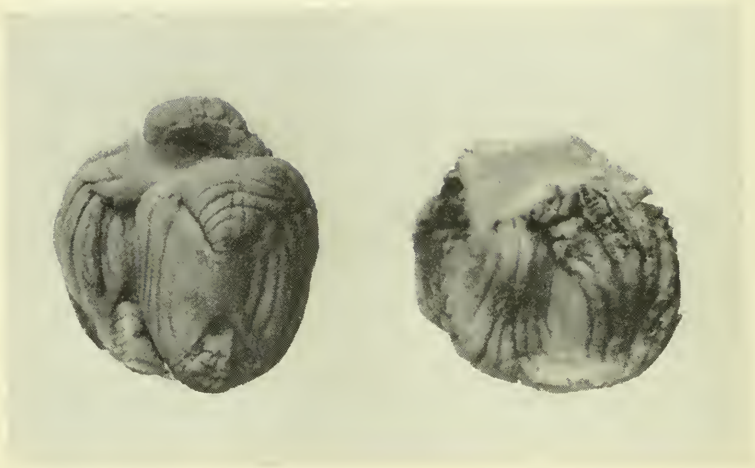
Rate of Feathering in Rhode Island Reds. (Page 92)
Above: Genetically late feathered female at eight weeks.
Below: Genetically early feathered female at eight weeks.



Rate of Feathering in Rhode Island Reds.

Above: Genetically late feathered male at eight weeks.

Below: Genetically early feathered male at eight weeks.



Nutritional Gizzard Lesions in Chicks. (Page 73)

Left: Normal chick gizzard.

Right: Chick gizzard showing severe lesions.

The seed which is to be cleaned is fed from a funnel into a rectangular chamber about 2 inches wide, 24 inches high, and 48 inches long. A blast of air obtained from a 12-inch fan is directed through this chamber. A removable trough at the bottom of the chamber serves to collect the seed. The seed in the trough will be graded from heavy to light, the best seed being found near the front end and the very light seed at the far end of the trough. The chaff is blown to the far end and caught in a container below the device. The operator arbitrarily decides the division point between seed which is to be used and that which is to be discarded.

DEPARTMENT OF ENTOMOLOGY

Charles P. Alexander in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne and W. D. Whitcomb, Waltham.)

Oil Sprays for Dormant Applications. The winter and early spring of 1938 reflected in considerable measure the abnormal weather conditions which culminated in the September hurricane. Heavy rains in January removed most of the snow, which was not replaced to any extent during the remainder of the winter. Very few periods of subzero temperatures were experienced so that, while the winter was somewhat more severe than the previous one, little or no damage was caused to fruit buds except in the most exposed locations. Unusually warm weather in late March and throughout most of April caused a rapid advance in seasonal development, so that orchards were ready for the dormant and delayed dormant applications of oil sprays fully 10 days earlier than normal. The lack of snow and early thawing of the ground combined to give excellent conditions for spraying and allowed accurate timing of the oil sprays, while the consistently warm weather following their application prevented injury from these sprays so that orchards throughout the State were remarkably free from this type of damage.

The European red mite infestation in the college orchards was slightly heavier than in 1937 but was very light in comparison to other years. All of the oils gave 96 percent control or higher and no serious increase in mite population was noted throughout the season, a fact which would have been more significant if the original infestation had been heavier.

The new type of oil containing 96 percent mineral oil and 4 percent dinitro-ortho-cyclo-hexy-phenol, which was first applied in 1937, was again tested. A special goulac-bentonite mixture is furnished by the manufacturer to emulsify this oil. Considerable difficulty was experienced in this process due to the faulty condition of the emulsifying agent. It was necessary to secure a special shipment of newly prepared emulsifier before the spray could be applied. A more stable emulsifying agent would be desirable. Once thoroughly prepared, however, this oil spray proved very effective against eggs of the red mite and caused no injury to fruit buds.

Substitutes for Lime-sulfur in Summer Sprays for Orchards. Tests with these materials were conducted in the college orchards, in cooperation with the Departments of Pomology and Botany. Commercial liquid lime-sulfur with spray catalizer was applied in pre-blossom and calyx sprays, followed by micronized sulfur in the 4 cover sprays. Liquid lime-sulfur was also used at diminishing strengths through the calyx spray: i. e., 1-50 in the pre-pink, 1-60 in the pink, and 1-70 in the calyx, followed by micronized sulfur in the cover sprays. A mixture of dry lime-sulfur and finely divided sulfur was employed throughout the season in the proportions of dry lime-sulfur 3 pounds and sulfur 5 pounds per 100 gallons in the pre-pink and pink, dry lime-sulfur 2 pounds and sulfur 4 pounds in the calyx, and dry lime-sulfur 1 pound and sulfur 4 pounds in the cover sprays. Variations of the standard schedule were also tested. Micronized sulfur and both the paste and dry forms of flotation sulfur were applied following liquid lime-sulfur in the calyx and pre-blossom sprays.

Lead arsenate was used in all cases at the strength of 3 pounds per 100 gallons in the pink and 3d cover sprays; 4 pounds in the calyx, special curculio, 1st and 2d cover sprays; and 2 pounds in the 4th cover spray. It was omitted in the pre-pink application. Owing to the unusually early season the 1st cover and previous sprays were applied from 7 to 10 days in advance of the normal dates for those applications. To compensate for such conditions and to make succeeding sprays conform to the usual schedule, a special application was made for curculio control. Linseed oil as a sticker was used in the 1st cover and special curculio sprays.

Examination of the trees in the experimental plots in late May showed that in all plots on which liquid lime-sulfur had been applied according to the standard program there was considerable crinkling of the leaves with some marginal burn, particularly as a result of the calyx application. No scab spots were observed even in the tops of the trees. The foliage on the trees which had been sprayed with diminishing strength of lime-sulfur showed as much injury as that on which standard strength of lime-sulfur had been used. In the plots where lime-sulfur with spray catalizer and dry lime-sulfur with sulfur had been applied, there was less foliage injury, as regards both crinkling and marginal burn, than where liquid lime-sulfur was used. There was no evidence of scab in any of these plots. On both the McIntosh and Baldwin check trees there was no crinkling of the leaves nor other evidence of spray burn. There was considerable evidence of scab on unsprayed McIntosh trees. Leaf roller, tent caterpillar, gypsy moth, and bud moth were found on the unsprayed Baldwins.

On May 15 there occurred a brief storm which was accompanied by high winds and was, in effect, a mild foretaste of the September hurricane. Many trees were blown down, and on the east and southeast exposures much foliage was badly wind-torn. Undoubtedly some spray burn was masked by the browning of foliage resulting from this wind injury.

On September 10 the experimental plots were inspected to note comparative effects of the different sprays upon fruit and foliage just before it was anticipated that harvesting of the McIntosh would begin. The unsprayed McIntosh trees showed much scab on foliage. Practically all the fruit was infected and many apples were badly cracked. In the dry lime-sulfur–sulfur plot there was a considerable amount of foliage injury and russeting of fruit. In the other plots there was almost complete recovery from early burning and practically no late summer injury or russeting of fruit. A somewhat blotchy spray deposit on fruit was noted in the plots where flotation sulfur was used, but no russeting occurred. Very little scab was noted on either fruit or foliage. On Baldwins the dry lime-sulfur–sulfur combination caused considerable leaf burn and slight russeting of fruit. A much milder type of injury was noted on the foliage in the lime-sulfur–spray catalizer and diminishing strength lime-sulfur plots, and no russeting of fruit. Practically no injury was noted on the flotation sulfur plots or on the trees given the standard schedule with micronized sulfur in the sprays following the calyx.

No record of harvested fruit could be made. The hurricane of September 21 blew off all the fruit and broke down many of the trees in the experimental block. The high wind also scattered the fruit so generally from one plot to another that it was impossible to determine whether the apples under one tree dropped from that tree or were carried from one several rows away.

Control of White Apple Leafhopper. (W. D. Whitcomb, Waltham.) The white apple leafhopper was generally abundant in Eastern Massachusetts orchards. In some orchards infestations as high as 25 hoppers per leaf developed and in others the average was 1 to 4 hoppers per leaf.

A finely ground dust containing 55 percent sulfur and .123 percent pyrethrins was widely used. In most cases this dust gave good control, but the results varied with the thoroughness of application and the weather conditions when applied. Actual counts in one orchard where this dust was applied to three different blocks of trees on different days showed reductions of 96.94 and 76.19 percent in the number of live hoppers per leaf on McIntosh, and 51.13 percent on Delicious. In the experimental orchard, counts two days after application showed that the sulfur–pyrethrum dust gave 88 percent reduction of hoppers and was 35 percent more effective than a standard pyrethrum–clay dust (30-70) containing about twice as much pyrenthrins.

Nicotine sulfate 1-800 with or without soap and a pyrethrum extract containing 2.2 percent pyrethrins 1-800 with either fish oil soap or cocoanut oil soap all reduced the leafhopper population more than 90 percent. When counts were made 10 days after the application, however, the nicotine sprays had maintained the high percentage of reduction while the hopper population on the pyrethrum-sprayed trees had increased by 16 and 25 percent, indicating considerably more residual effect from the nicotine. A commercial oil–pyrethrum mixture 1-600 (DX) maintained its high degree of control for 10 days, but cube powder with resin residue emulsion, an oil–rotenone mixture (Standard Chem. Co.) 1-800, and a dinitrophenol material (cyclonox) 1-800 and 1-400 permitted a slight increase in hopper population 10 days after application.

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) In spite of abnormally warm weather early in the spring, the maximum emergence of the plum curculio and the critical period in its control did not occur in 1938 until June 6 to 13, about 3 weeks later in relation to tree development than normal. The usual application of the first cover spray was made May 20 to 25 with good results, but the delayed activity necessitated another application June 8 to 10 which was not called for in the recommended schedule.

During the period from May 19 to 27, trees in the experimental orchard were sprayed when the fruit on them had grown to approximately 4/16, 5/16, and 6/16 inches in diameter. An examination of 19,000 apples showed noticeably better protection when sprayed at the 5/16-inch size even though these applications were made on successive days. On Gravenstein the application at 4/16-inch size permitted 13 percent more curculio injury and was apparently too early; and the application at 6/16-inch size showed 16 percent more curculio injury, being apparently too late. On McIntosh, the apples sprayed at 5/16-inch size were damaged only about one-half as much as those sprayed when the fruit was 6/16 of an inch in diameter, and about one-third as much as the 4/16-inch size fruit.

During this period (May 19 to 27) the apples grew approximately 1/16 inch in diameter each day, indicating the great importance of timeliness of application for curculio control.

Apple Maggot Control. (A. I. Bourne and W. D. Whitcomb.) Apple maggot proved to be more abundant than in 1936 or 1937, and even in well-sprayed commercial orchards the pest was present in greater numbers than would be expected following a thorough spray or dust program. This was due in part to the fact that many growers relaxed their vigilance and took less care in the prompt disposal of dropped apples. The decline in numbers of the pest in the last few years and the low price of apples caused many of the growers to curtail their spray program and give less attention to orchard environment. As a result, large numbers of flies were present in the orchards late in the season and caused a heavy infestation of late varieties. The record of emergence of apple maggot flies made by Professor Whitcomb at Waltham is as follows:

Date of Emergence of Apple Maggot Flies from Cages, Waltham

	In Sun—Light Soil	
	Cultivated	Sod
1st fly	June 22	July 5
25% flies	July 7	July 13
50% flies	July 11	July 16
75% flies	July 19	July 19
Last fly	August 7	August 3

The number of flies emerging equaled 34.6 percent of the total, an increase of 13 percent over the emergence in 1937 and slightly more than that of the previous year.

Following the hurricane, much of the fruit remained on the ground long enough to allow the maggots to reach full development and enter the soil for pupation. This in all probability will lead to a great increase in the emergence of flies in 1939 with a correspondingly greater danger to next year's crop, and threatens to place apple maggot once more in the forefront of orchard pests.

Biology and Control of the Apple Leaf Curling Midge. (W. D. Whitcomb, Waltham.) In 1938, the area known to be infested by the apple leaf-curling midge was extended nearly to the center of the Nashoba fruit belt of Middlesex and Worcester Counties when this insect was found for the first time at Groton, near Ayer; Littleton (near Lake Nagog); Littleton Common, North Littleton, Concord, and Lexington. Also, an apparently isolated infestation at Sanford and Alfred, Maine, was extended to North Berwick, Maine. All of these newly infested localities are in a southwesterly direction from previously known infestations, indicating that favorable air currents during the emergence period of first brood flies were responsible for this dispersion.

The emergence of first brood flies extended from May 24 to June 17 with a maximum on May 31. Rolled leaves infested with midge maggots were abundant from May 31 to June 10, and the maggots migrated to the bark and soil in large numbers from June 14 to 28. Eggs and flies were again abundant July 1 to 15 and all available new growth was rolled by July 18 when the second brood of maggots began to migrate. Heavy rains from July 18 to 24 caused many maggots to leave the rolled leaves prematurely, and after August 1 there was considerable overlapping of generations. A small third generation of flies emerged in late August and larvae were migrating from infested leaves as late as September 16.

In the laboratory only 12 percent of the maggots which were overwintered in cages emerged as flies. Of the first generation maggots which were collected before July 19, over 95 percent transformed to flies; and 48 percent of the second generation maggots maturing from July 19 to August 9 transformed; while only 7 percent of those maturing from August 19 to 26 emerged as flies. The length of time required for mature maggots to change to adult flies averaged 21 days in June, 17 days in July, and 24 days in August.

When flies emerging July 6 to 9 were dissected, an average of 127 eggs per female was found in 1-day-old flies, and 139.9 eggs in flies 2 days old. The greatest number of eggs found per female was 231.

None of the maggots covered with 2 inches of soil in laboratory cages emerged as flies, while 18.5 percent of those under 1 inch or less transformed, and 48 percent of those on the surface completed their development.

Experiments with soil treatments applied just before the flies begin to emerge, as determined by collections of adults in cloth cages covering 15 square feet, indicate that naphthalene flakes either broadcasted on the surface or spaded into the soil gave very good control of midges in the soil. When naphthalene flakes were applied at the rate of 2 pounds to 100 square feet, either by broadcasting or spading, the number of flies emerging was reduced 94.6 percent. Spading alone reduced them 71 percent; Cyanogas at the rate of 1 pound per 100 square feet reduced them 86.9 percent; and tobacco powder containing 1 percent nicotine was 60 percent effective.

The Spray Residue Problem. (A. I. Bourne.) There was no particular spray residue problem in Massachusetts in 1938. Aside from the fact that the September storm made windfalls of a large proportion of the crop, the rain which preceded it had removed most of the spray deposit from the fruit. Including the 12 inches of rain which fell in the days immediately before the hurricane, the total precipitation from July 30, the date of the last cover spray, until September 21 was 16.39 inches. In the 70-day period from the third cover spray to the same date there was an accumulation amounting to 23.09 inches and from the second cover spray the rainfall totaled 28.61 inches. The fruit, therefore, encountered nearly as much rainfall, from the time it received the last full dosage of lead arsenate until the anticipated date of harvest, as the total normal precipitation from January to August.

In early September notice was received that the limit of tolerance for lead for the 1938 shipping season had been raised from 0.018 grains per pound of fruit to 0.025 grains; and in November the limit of 0.02 grains per pound, or double the previous tolerance, was announced for fluorine compounds. This action will materially lighten the burden on the fruit grower and allow much greater latitude in the spray program.

In a study of methods to supplement lead arsenate in the control of orchard pests, experiments with chemically treated codling moth bands were continued in the same orchard as in 1937. In addition to the banding of the trees, the regular spray schedule was supplemented by two extra applications of a fixed nicotine compound in an effort to check late season "stings." There, as in the orchards at the college, the intervention of the hurricane prevented checking the fruit in the experimental blocks. The apples were blown about for such distances that there could be no certainty as to the particular plots from which they originally came, and the fruit was in many cases so badly bruised that minor insect blemishes were not distinguishable. By late fall, however, the trees in this orchard had been pulled back into an upright position so that most of the codling moth bands could be removed and examined.

A total of 3,287 larvae was collected from 210 trees, or an average of 15.7 larvae per tree. In the previous year 4,078 larvae were collected from 248 trees, or an average of 16.4 larvae per tree. The Northern Spy trees in this orchard had practically no fruit in 1937, but bore a full crop in 1938. While the total number of larvae collected in the entire orchard in 1938 was very close to the record in 1937, nearly one half of the number was found on the Northern Spy trees, which showed an average of 45.5 larvae per tree, while the average for all other varieties was 10.5 larvae per tree. Comparison of the collections from the other varieties showed a material reduction in codling moth population in 1938 from that of the previous year. On several trees two bands were set, one above the other, on the main trunk, in an effort to determine what proportion of the larvae moved down the trunk to the bands or crawled up from the ground. All but one of these trees were blown over, the trunks split open, and the bands reduced to fragments. On the one tree where the bands were intact, 54 larvae were collected in the upper band and 32 in the lower.

Introduction of Parasites of Oriental Fruit Moth in Peach Orchards. (A. I. Bourne.) In 1938 the work of rearing parasites of the oriental fruit moth was conducted in the entomological laboratories at Amherst. By agreement with the Entomology Department of the Connecticut Experiment Station, the services of Mr. A. DeCaprio were secured from June 1 to July 15. Mr. DeCaprio was in direct charge of the collection of breeding material in New Jersey, its shipment to Amherst, and later the distribution of parasites in the peach orchards. The facilities of the laboratory proved very satisfactory for the proper care and handling of the breeding material, and there was sufficient emergence to fill the original orders for 16,000 parasites. Because of low mortality in the breeding material and a higher degree of parasitism than anticipated, it was possible to fill late requests for colonies and leave a small surplus of parasites which were liberated at the discretion of the county agents. In all, more than 20,000 parasites, *Macrocentrus ancylivorus*, were liberated in late June and early July, in 58 orchards in 9 counties of the State.

The rainfall in July, as recorded at the college, was nearly twice the normal for that month, and some parts of the State experienced even heavier precipitation. The frequent showers, with intervening periods of high temperature and humidity, proved almost ideal for the development of the oriental fruit moth, and at the same time constituted the worst possible conditions for the activities of the parasites, so that on the whole the *Macrocentrus* parasites released in Massachusetts peach orchards in 1938 proved less effective than in any year in which liberations have been made. While early twig infestation by the fruit moth larvae was not extensive, late season damage to fruit was severe in many orchards. Similar weather conditions prevailed over much of Connecticut where results with the parasites corresponded with those in Massachusetts. In New York and Ohio, however, the prevailing weather was more nearly normal as regards temperature and humidity, and the results with *Macrocentrus* and similar parasites were very satisfactory, indicating that under normal midsummer conditions favorable results can be expected from the parasites liberated in the orchard. Even under the adverse weather conditions prevailing in Massachusetts during the season of 1938, the few growers who purchased a sufficient supply of parasites to allow the ratio of 1 colony to approximately 300 trees reported the fruit at harvest to be relatively free from fruit moth damage.

Control of Cabbage Maggot. (W. D. Whitcomb, Waltham.) Eggs of the cabbage maggot were first found in the field on April 29. This is about a week earlier than the first oviposition in other years, because of the unseasonably warm weather in late April.

Cabbage maggots were normally destructive. The abundant and well-distributed rainfall in May and June stimulated the growth of secondary roots on infested plants so that the majority of them produced marketable heads. Under these conditions only 4 percent of the untreated plants in the experimental field were killed, although 76 percent of them showed moderate or severe injury to the roots by the maggot. Furthermore, 62 percent of them produced marketable heads, which was the best yield from untreated plants in several years.

Nevertheless, control treatments were effective and worth while. Corrosive sublimate solution (1 ounce in 10 gallons of water) gave 97 percent protection when applied once and 100 percent protection when applied twice and produced

90 percent salable heads. Applications to the roots at the time of transplanting, using pure calomel powder and calomel–talc mixtures containing 75, 50, and 25 percent calomel, all gave about 90 percent protection. Mixtures containing 10 and 5 percent calomel were not effective. Actually, the 75 percent calomel–talc powder gave the greatest protection, but the advantage over the 50 percent mixture was so little that the latter seems more practical. Both the 75 and the 50 percent calomel–talc mixtures gave slightly more protection than pure calomel, apparently because of the better adhesiveness of the talc. Plants treated with pure calomel wilted considerably when first transplanted but recovered quickly after root growth was stimulated by rain.

Maggot injury to plants which received root treatment when transplanted was confined almost entirely to the upper part of the root which grew after the treatment was applied. This type of injury is much less destructive than when the feeding roots are eaten, and seldom checks the growth of the head severely.

Cabbage Maggot in Radishes. (W. D. Whitcomb, Waltham.) Radish seeds were planted at approximately 10-day intervals from May 2 to August 15. One lot of seed was untreated and one lot received the calomel seed treatment at the rate of ½ pound of calomel powder on each pound of seed. Approximately one month after the seed was sown, 100 radishes selected at random were examined and the injury by cabbage maggot classified. Appreciable injury, making more than 15 percent of the radishes unmarketable, was found only in the May 2 and 12 plantings and again in the June 14 and 22 and July 2 plantings.

Calomel seed treatment and weekly applications of a .6 percent rotenone dust in the latter part of the season failed to protect the radishes, and no effective economical control of this insect on radishes was secured. These experiments indicate, however, that radishes can be grown profitably if the seed is sown so as to avoid the periods of maggot activity as shown above.

Control of Striped Cucumber Beetle on Cucumbers and Melons. (W. D. Whitcomb, Waltham.) In 1938, striped cucumber beetles were extremely abundant and in the experimental planting 3773 beetles were recorded compared to 685 beetles in 1937. In these plantings, which contained an equal number of cantaloupes, melons, and cucumbers, 65 percent of the beetles were found on the cucumbers indicating a decided preference for that plant.

The results in the experiment are somewhat handicapped by an unusual and unexpected migration of beetles from near-by plantings of cucurbits. This was especially noticeable in July when hills of cucumbers and melons which had been kept practically free for a month suddenly became infested with 25 to 40 beetles each.

Sprays and dusts were applied 6 times between June 10 and July 14 at intervals of 4 to 10 days. Rain fell during each of these intervals and determined the length of interval between applications. On June 26-29 rain fell on 4 successive days and on July 11-13 on 3 successive days. During these rainy periods the beetles migrated to the plants which were washed free of insecticides and heavy reinfestations developed, especially on July 13 when 1937 beetles were counted on 90 hills.

Records of the effectiveness of insecticides were taken by counting the number of beetles present just before spraying or dusting and again 24 hours after treatment. On this basis cube–clay dust containing .75 percent rotenone reduced the beetles 93.8 percent throughout the period and gave the best protection. Cube–clay dust (.6 percent rotenone), copper oxychloride–lime dust 1-14 (DuPont), copper–rotenone dust (.8 percent rotenone) (Gen. Chem.) and calcium arsenate–lime dust 1-14 all gave 90 to 92 percent protection. Micronized rotenone–sulfur dust (.75 percent rotenone and 20 percent sulfur) was the least effective of the dusts used. Wettable cube and derris sprays (4 pounds in 100 gallons) gave 83.4 and 84.4 percent protection and were slightly inferior to the dusts.

On this basis the effectiveness of all the treatments is within the range of experimental error, indicating that the calcium arsenate–lime dust, which is the cheapest, was the most practical under 1938 conditions.

Control of Squash Vine Borer. (W. D. Whitcomb, Waltham.) The average field infestation by the squash vine borer in the experimental planting of Hubbard squash in 1938 was 6.67 borer tunnels per vine, which is much greater than has been recorded here before. Many vines were killed before they had grown secondary roots at the nodes, and frequent and excessive rainfall during July reduced insecticide treatments to about one-half their usual efficiency. Almost continuous rainfall from July 18-25, which practically prevented dusting or spraying, only slightly reduced oviposition by the borer moths and greatly aided the development of an unusually severe infestation.

Insecticides were applied July 6, 13, 22, 29, and under these conditions 40 percent nicotine sulfate 1-250 permitted an average of 3.06 borer tunnels per vine, which is a reduction of 54.12 percent over the infestation in the untreated plants. Cube–clay dust (.6 percent rotenone), wettable cube spray (4 pounds in 100 gallons), and a neutral copper–rotenone dust (.8 percent rotenone), all reduced the infestation approximately 45 percent. Nicotine sulfate 1-500+oil emulsion 1 percent and cube–clay dust (.75 percent rotenone) were less effective in the record but obviously were affected by the unfavorable weather conditions.

Potato Spraying Experiments. (A. I. Bourne.) Potato flea beetles appeared in the fields almost as soon as the young plants appeared above ground, and were so abundant that they constituted a major problem throughout the season. Leafhoppers were late in appearing and were at no time very abundant. The rainfall in July was 7.45 inches, a record exceeded only three times in the last fifty years. This heavy precipitation during July very largely prevented aphid attack, and no serious outbreaks in potato fields were noted or reported.

The frequent rains during June and July made it difficult to hold to any definite schedule of sprays, and applications were frequently interrupted. However, the experimental plots were given 10 applications of copper sprays between June 14 and August 29. Six different insecticides were tested on the standard variety, Green Mountain, each of them being used in combination with 5-5-50 and 5-3-50 Bordeaux mixture in the applications from July 14 to August 9. As thorough coverage of the foliage as weather conditions permitted was maintained throughout the season, and the plants remained green until killed by the frost of October 7-8. Weekly records of flea beetle damage were made in each plot throughout the season. The ranking of each material with the two strengths of Bordeaux mixture was as follows:

With 5-5-50 Bordeaux	With 5-3-50 Bordeaux
Derris 4 percent rotenone	Cube
Cube 4 percent rotenone	Derris
Calcium arsenate (Calrite)	Commercial 2 percent rotenone
Commercial 2 percent rotenone	Calcium arsenate-arsenite mixture
Calcium arsenate (Calgreen)	Calcium arsenate (Calrite)
Calcium arsenate-arsenite mixture	Check (Bordeaux alone)
Check (Bordeaux alone)	Calcium arsenate (Calgreen)

All of the materials gave better control with the 5-5-50 Bordeaux mixture, indicating that in a year of frequent and heavy rainfall, as in 1938, the greater persistence of the high calcium Bordeaux gave added protection to the foliage. This was also borne out in the relative yields as shown in the following table:

Material	With 5-5-50 Bordeaux		With 5-3-50 Bordeaux	
	Yield per Acre Bushels	Percentage of Crop Grade 1	Yield per Acre Bushels	Percentage of Crop Grade 1
Check (Bordeaux only)	478.3	78.4	475	74
Derris (4 percent rotenone)	480	78.5	478.4	73.2
Cube (4 percent rotenone)	471.6	75.1	466.7	71.1
Commercial 2 percent rotenone	457.5	83.1	456.7	74.4
Calcium arsenate (Calrite)	451.6	72.3	446.7	70.1
Calcium arsenate-arsenite	431.6	72.6	328.4	70
Calcium arsenate (Calgreen)	416.6	75.2	415	57.4

All of the materials gave slightly higher yields with the 5-5-50 Bordeaux. The commercial calcium arsenate–arsenite mixture when used with 5-3-50 Bordeaux caused severe burning of the foliage, which was reflected in the low yield.

Two commercial brands of copper sprays designed for use on potatoes were compared with 5-5-50 Bordeaux mixture. Tests were also made of the value of excess lime with each of these materials. Ten applications were made during the season. The relative value of the materials, based on yields, was as follows:

Material	Yield per Acre Bushels	Percentage of Crop Grade 1
Bordeaux 5-5-50	524.1	75.4
Basic copper sulfate+lime	478.6	74.3
Basic copper sulfate	433.2	65.6
Copper hydro+lime	407.5	73.4
Copper hydro	348.9	57.8

The addition of lime to the commercial materials in each case improved the coverage and adhesiveness of the sprays. None of these sprays, however, equaled homemade Bordeaux in these qualities, and the superiority of the Bordeaux-sprayed plots was apparent throughout the season. The correlation of increased yields and superiority in coverage and persistence indicates that these were very important factors in a year such as 1938 when the rainfall during the spraying season was more than double the normal.

In the period of unsettled weather which culminated in the hurricane, there was a total rainfall of approximately 12 inches which not only completely saturated the soil but actually flooded parts of the experimental plots. The soil dried very slowly, and in low areas still retained much moisture at the time the potatoes were dug. The saturation of the soil prevented proper aeration and exerted a smothering action on the tubers which led to internal breakdown. This condition, which was noted in practically all of the plots regardless of treatment and in fact was generally distributed throughout the entire Valley, materially reduced the net yield. The damage was much more severe in those low areas which were submerged by the high water, and was another by-product of the hurricane.

Control of Onion Thrips. (A. I. Bourne.) Weather conditions during late spring and early summer were as a whole favorable for the onion crop. Moderate temperatures and ample rainfall promoted rapid growth while thrips were somewhat late in appearing and developed slowly. The prolonged warm period from June 18 to 24, with little or no precipitation, threatened the appearance of blast, but the intervention of nearly 5 inches of rain on June 26 and 27 accompanied by comparatively low temperature halted the blast and at the same time retarded the development of thrips, so that at the beginning of July fields of seed onions throughout the Valley were in excellent condition and showing promise of a heavy crop.

The 10-day period from July 8 to 17 was marked by high temperature and very little rainfall. These conditions gave considerable impetus to the seasonal development of thrips, and the infestation became general and increased rapidly in severity. Fortunately the plants by that time had made excellent top growth and no serious damage was caused. In the experimental plots the infestation reached its maximum on July 26 with an average of 108 thrips per plant, and declined rapidly from that point.

Blast appeared soon after the period of very warm weather which culminated in the 87° maximum on July 17, and it spread rapidly throughout the Valley. While the thrips were not abundant enough to cause serious damage to normal, healthy plants, their presence in fields stricken by blast served to intensify the damage and hasten the death of the plants.

Field tests were made of a commercial spray containing 2 percent rotenone; ground derris and cube, each with a 4 percent rotenone content; a pyrethrum–sulfur compound; a fixed nicotine–oil combination; and the standard nicotine sulfate-soap mixture. In addition 3 dusts were tested: a pyrethrum–sulfur mixture, cube–vatsol, and dual-fixed nicotine. Two applications were made 7 days apart. The relative effectiveness of these materials is shown in the following table.

Treatment	Average Number of Thrips per Plant			
	Before 1st treatment	1 day after 1st treatment	7 days after 1st and just before 2d treatment	1 day after 2d treatment
Sprays				
Commercial 2 percent rotenone	67	18.4	20.7	2.5
Derris	34	3.4	8.7	1.6
Cube	69	3.5	9.2	11.1
Ortho nicotine–oil	56	8	8.1	1.2
Pyrethrum–sulfur	60	9.1	13	3
Nicotine sulfate–soap	54	0.6	8.7	0.5
Dusts				
Pyrethrum–sulfur	71.5	31.5	15.3	1.6
Cube–vatsol	51	19.5	26.5	6.6
Dual-fixed nicotine	49	7.9	22.7	4.5
Check	54	—	25	—

Superior coverage and penetrating qualities made the sprays more effective than the dusts, although dual-fixed nicotine compared very well with the control furnished by the sprays. Dusts also showed little residual effect or retardation of reinfestation. Nicotine sulfate was superior to other sprays in its immediate effects in both applications. The rotenone sprays were somewhat slower in killing action, but showed a pronounced residual effect which checked reinfestation. The ortho nicotine-oil combination was superior to all others in its prolonged protection of the plants from attack, as shown in the table.

Studies on varietal resistance of different strains of onions to thrips attack were cut short by the early appearance and rapid spread of blast in the area where the variety plots were located. Selzers Sweet Spanish, Nebraska, Grano, and an unnamed variety designated McL No. 1, were noticeably resistant to thrips attack with an average of only 6 to 9 thrips per plant, while the infestation on less resistant varieties varied from 70 to 80 thrips per plant. Also Nebraska was the last variety to succumb to blast, remaining upright and comparatively free from thrips when the plants in all other plots were flat.

Insecticides for the Control of European Corn Borer. (A. I. Bourne.) The weather during the month of April was unusually mild and at the end of the month the season was considerably in advance of normal. May, however, was more nearly normal although there were several periods when the temperature at dusk was unseasonably low and frosts occurred at intervals as late as the last 2 days of the month. Pupation of European corn borer larvae began much earlier than usual. Observations in southern Hampden County showed that on light, early soil from 75 to 100 percent pupation had taken place by May 11. Moths from material collected on that date began to emerge on May 16. In heavier soil and in less exposed fields pupation was considerably later, and emergence was delayed by the comparatively cooler weather during May. The low temperature at dusk and the frost late in the month retarded the activity of the moths and correspondingly prolonged the period of egg laying, while the irregularity in development in different fields was much greater than normal. Under such conditions accurate timing of the first application of sprays or dusts was particularly difficult.

Field tests with 3 dusts, dual-fixed nicotine, cube-vatsol, and a commercial rotenone, and with 4 sprays including ground derris, cube, and 2 commercial rotenone sprays, were conducted in a commercial planting in Hampden County. Both sprays and dusts were applied at 5-day intervals from June 10 to June 25, the first application based on the general appearance of the young larvae.

The infestation throughout the entire planting of several acres was very heavy. Unsprayed corn yielded only 25 to 35 percent borer-free ears in the first picking and approximately 16 percent in the second.

All of the insecticides proved toxic to corn borer larvae and furnished satisfactory protection for the period covered by the schedule. The degree of control was not so high as in previous experiments owing partly to the unusually severe infestation and partly to the comparatively large number of larvae appearing very early as a result of the abnormal season.

The sprays gave satisfactory protection and the dusts fair commercial control on the basis of the borer-free ears harvested. The real value of the insecticidal treatments, however, is indicated by the relative proportion of the total yield which was of marketable grade. In the dusted plots from 62 to 65 percent of the crop was borer free and 50 to 56 percent was of marketable grade; in the sprayed plots from 75 to 80 percent of the total yield was borer free and 57 to 60 percent marketable; while in the unsprayed plots only 16 percent of the crop was borer free and less than 12 percent of the ears were fit for market.

The corn in the experimental plots matured very early and the entire crop was harvested by July 19. Because of the heavy infestation of other early corn in the market, the grower found a great demand for his crop and realized a sufficient premium on his borer-free corn to receive from his whole planting a return of approximately 3 to 4 cents per ear.

Insects Concerned in the Dispersal of Dutch Elm Disease. (W. B. Becker.) Studies on the biology of the native elm bark beetle, *Hylurgopinus rufipes*, were continued. A progress report on part of the work follows:

Examination of the contents of some larval galleries of *H. rufipes* showed that the number of instars varied, as many as eight exuviae being found in one completed gallery. A study of larvae of one generation collected at about weekly intervals from a pile of American elm logs, indicated that five instars was the most common number under the conditions of the experiment. A detailed account of the study will be published.

Mr. W. E. Tomlinson of the Waltham Field Station cooperated by carrying on some experiments with *H. rufipes* in Waltham. Elm logs cut in mid-April were attacked for oviposition purposes in late April and early May. Adults of the next generation began to emerge from the logs in early August. In early September elm logs cut in mid-July were observed being attacked by adult beetles. Since the experiment is not complete, it is not yet known whether brood galleries were made or not.

Mr. Tomlinson also carried on some experiments with *Scolytus multistriatus* in Waltham, a town within the area infested by these beetles. Adults were observed attacking a recently felled elm tree in small numbers in early May. Adults of this same generation which started to attack some elm logs in the vicinity at about the same time gave rise to a generation which began emerging in early August. Elm logs cut in mid-July and placed next to the above logs from which the beetles were emerging, were first observed to be attacked by adults in early August. Examination of this bark early in September showed the presence of eggs and parent adults in brood galleries. This study indicates that *Scolytus multistriatus* may have one complete and a partial second generation in the vicinity of Waltham.

Insect Pests of Shade and Ornamental Trees. During the summer the campus trees were examined for the presence of insect injury in order to form a basis for a spray program for pest control. In the fall a survey was made of the effects of the hurricane on shade and ornamental trees on the campus. Although not strictly entomological in nature, the survey pointed out some interesting entomological problems.

In addition to eleven species of insects infesting wood or wood products, 95 species of insects on 34 different genera of shade and ornamental trees were sent to the Shade Tree Laboratory for identification.

A bulletin of an economic nature on the control of shade tree insects was published (Mass. Agr. Expt. Sta. Bul. 353).

Control of Red Spider on Greenhouse Plants. (W. D. Whitcomb and William Garland, Waltham.) Further experiments with sprays containing extractives from derris and cube indicate that effective sprays of this nature for combating the common red spider, capable of giving 90+ percent control consistently, should contain .03 percent total extractives of which .0075 percent is rotenone. This is equivalent to a stock mixture containing 1½ percent rotenone and 4½ percent other resins, diluted 1-200. Sprays containing these active ingredients are slightly more consistent in effectiveness if combined with brown camphor oil rather than with soluble pine oil or sulfonated castor oil. The addition of .2 percent Karaya gum increased the effectiveness about 5 percent, apparently by building up the deposit on the leaves; but when both gum and spreader were added, the run-off was increased and no benefit from the gum resulted. At 80° F. the effectiveness against red spider was 25 to 40 percent greater than at 60° F.

An alcoholic extract of derris containing .0075 percent rotenone and .0225 percent other extractives was 10 percent more effective than a similar extract with .005 percent rotenone; and the addition of .005 percent pyrethrins not only failed to increase the mortality to red spider but actually gave an average decrease of 6 percent in three experiments.

The addition of Karaya gum increased slightly the effectiveness of commercial thiocyanate spray and a commercial selenium compound, but the greater run-off resulting from the addition of a spreader consistently reduced the mortality to red spider. Both of these materials were only moderately effective in single applications but gave promising results when repeated in three or four applications.

Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb, Waltham.) Experimental fumigations with chlorinated naphthalene compounds as greenhouse fumigants were continued with very encouraging results. A chlornaphthalene oil killed 92.51 percent of red spiders on carnation in one fumigation and 100 percent in two fumigations. Other chlornaphthalene compounds were slightly less effective, the mortality of red spider by fumigation decreasing about 5 percent for each atom of chlorine added to the naphthalene.

Mixtures of 2 parts of chlornaphthalene oil with 1 part of the higher chlorinated naphthalene waxes killed 100 percent of the red spiders in two fumigations, but in one fumigation the mortality of red spider decreased as the atoms of chlorine in the mixture were increased.

The addition of 25 percent paradichlorobenzene crystals to the chlornaphthalene oil gave a mortality of 89.42 percent; and a mixture of equal parts of chlornaphthalene oil, paradichlorobenzene crystals, and naphthalene crystals killed 92.92 percent of the red spiders.

The most effective mixtures were those containing 25 percent naphthalene crystals in chlornaphthalene oil and 25 percent chlorinated naphthalene soft wax in chlornaphthalene oil. Both of these mixtures killed all of the red spiders in one fumigation.

Potted carnations infested with the common red spider mite *Tetranychus telarius* L.) were used and no injury to the plants resulted from normal fumigations. The work was done in an experimental fumigation chamber with ½ ounce of the fumigant for each 1000 cubic feet and an exposure of 6 hours at 70° F. and 60 percent relative humidity.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920 Chapter 94)
Seed Control (General Laws, 1927 Chapter 94)
Dairy Law (General Laws, 1920 Chapter 94)
Advanced Registry Testing
Miscellaneous Work

Feed Control. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski, L. V. Crowley, F. A. McLaughlin, J. T. Howard.) During the fiscal year 1,721 samples of feeding stuffs were officially collected and examined in the control laboratories. The gross receipts from the registration of feeding stuffs in 1938 (calendar year) were $23,400, derived from 1,170 brands at $20 each.

Dairy Law. (P. H. Smith, J. T. Howard, H. L. Allen.) During the year ending December 1, 1938, 6,369 pieces of Babcock glassware were tested. Condemned glassware consisted of one milk test bottle and one pipette. One hundred and ten certificates of proficiency were awarded; and 227 creameries, milk depots, and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, seven machines were condemned.

Advanced Registry Testing. (P. H. Smith.) On March 1, 1938, the work of Advanced Registry Testing was transferred to the Extension Service. While this work has been supervised by this department since its inception in 1902, it was felt that better correlation could be brought about between Advanced Registry Testing and Cow Test Associations and that results could be made of greater practical importance if the transfer were effected.

Miscellaneous Work. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski.) Numerous analyses have been made for residents of the State and other departments of the college.

Summary of Miscellaneous Work, 1938

Materials sent in:	
Milk and cream, butterfat only	701
Milk, solids and fat	26
Ice cream, for fat	75
Feeds, from farmers and dealers	122
Feeds, from State Institutions	785
For other departments of Experiment Station and College:	
Dry matter, forage crops	461
Complete fodder analyses	7
Vegetables, fiber only	91
Grass and hay, water and protein	86
Feeds, fat and fiber	43

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, J. W. Kuzmeski, A. F. Spelman, Chemists; J. T. Howard, C. L. Whiting, G. E. Taylor, Sampling Agents; H. L. Allen, Laboratory Assistant.) Records for the year show that 122 firms have registered for sale in the State of Massachusetts 533 brands of mixed fertilizer and fertilizing materials and 55 brands of agricultural lime and gypsum. Results of analysis show that 66 percent of the mixed fertilizer brands, 83 percent of the unmixed fertilizer brands and 75 percent of the lime brands showed no deficiences. The gross receipts from the registration of the fertilizer and lime products and from fertilizer tonnage fees for the year 1938 were $15,792.36.

For about ten weeks, beginning April 1, three experienced men employed to draw samples for inspection purposes sampled 23,142 sacks or containers, representing 18,153 tons of materials; 187 towns were visited, and 1,793 samples representing 514 brands were drawn from stocks found in the possession of 516 agents or owners. The following summary shows the character of these substances, as well as statistics with reference to their inspection.

	Brands Registered	Brands Collected	Samples Drawn	Number of Analyses	Number of Determinations
Mixed fertilizers	343	340	1,074	451	7,666
Ground bone, tankage and fish	48	48	150	53	624
Nitrogen products, mineral and organic	54	44	222	134	628
Phosphoric acid products	28	28	135	33	285
Potash products	13	17	67	26	147
Dried pulverized natural manures	30	30	107	31	286
Nitrate of potash	5	5	17	7	54
Peat products	2	3	5	3	21
Wood and cotton hull ashes	7	7	12	12	99
Miscellaneous	3	4	6	4	31
Lime products	55	53	133	61	628
Totals	588	579	1,928	815	10,469

During the period July 1, 1937 to July 1, 1938, the tonnage of fertilizer and plant food sold in Massachusetts was as follows:

	Fertilizer (Tons)	Plant Food Elements (Tons)		
		Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	45,339	2,355	3,796	3,326
Unmixed fertilizer chemicals and materials	22,360	1,434	2,015	745
Pulverized natural manures	1,476	32	25	41
Totals	69,175	3,821	5,836	4,112

Full details of the fertilizer and lime inspection will be found in Control Bulletins 95 and 97

Miscellaneous Analytical and Diagnostic Work. (H. D. Haskins, H. R DeRose, A. F. Spelman, J. W. Kuzmeski.) Chemical studies in cooperation with several departments of the Experiment Station, Field Station, County Agents and men in charge of the Soil Conservation work of the State have been carried on. The character and extent of this work is shown in the following summary:

Apples for ash analysis	18
Apple spray residue	5
Apple tree leaves, ash analysis	35
Cranberry spray residue	4
Fertilizer mixtures	24
Fertilizer chemicals	2
Fertilizer for manganese determination, A.O.A.C	6
Fertilizers for basicity and acidity determinations, A.O.A.C	4
Forage and field crops	276
Grain rations	2
Limestone, dolomite, A.O.A.C	9
Liquid lime-sulfur	7
Maple syrup	1
Peat	1
Potato spray	1
Salt water sedges and grasses	1
Seed residues	4
Total	400

Other work of the department has included consultations on various projects where chemical problems were involved. Research on problems developed by the referees of the Association of Official Agricultural Chemists of North America has received the usual attention and has included work on methods for the determination of manganese and acidity-basicity in fertilizer mixtures, the chemical work involved in these studies being performed by Mr. J. W. Kuzmeski and Mr. A. F. Spelman respectively. A considerable variety of chemical work has, as usual, been done for other State Institutions, community organizations, firms and individuals having problems of agricultural interest. This group includes the analyses of the following materials:

Animal tissues for mineral poisons	4
Crab and lobster shell meal	1
Dehydrated poultry manure	2
Ground bone	2
Hide scrapings	1
Hoof meal	1
Lime products	7
Miscellaneous	3
Mixed fertilizers	13
Nitrate of Soda	1
Organic waste product from caffeine plant	2
Orchard hay for spray residue	6
Peat	5
Peat poultry manure	1
Refuse from duck pens	1
Servall stable bedding	1
Sheep manure-wool waste	1
Soil	3
Wool waste	2
Total	57

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) Snapdragon rust was much less virulent on plants in the field this year. Heavy infection usually shows on susceptible varieties by August 5 but this year it did not occur until about August 10, which is 10 days later than normal. The cool temperature during the early summer months and the heavy rainfall in the latter part of July apparently prevented normal dissemination and germination of the rust spores.

Selection and hybridizing work is being continued with the most promising of the rust-resistant strains developed at the Field Station. The loss of plants through prevalence of wilt and blight diseases has interfered with pollination work in the field. Therefore all hybridizing has been confined to the greenhouse during the winter months, which has reduced the number of generations that can be grown each year from two to one.

Considerable variation has been observed in susceptibility of the different Field Station strains to the wilt and blight diseases, but sufficient data are not available to determine how much of this is due to climatic conditions and how much to heredity.

A number of rust-resistant varieties of snapdragons sold for garden use have been tested in the field over a period of two years. Many of these are highly resistant to rust but several were observed to vary greatly in type of foliage, habit of growth, and blooming quality, as compared with more susceptible varieties. Out of some 25 strains tested at Waltham the following were found to be the most desirable for garden use.

Variety	Flower Color	Variety	Flower Color
Alaska	White	Fair Lady	Pink
Buttercup	Yellow	Loveliness	Light pink
Campfire	Bronze	Maximum White	White
Daffodil	Yellow	Opal Queen	Salmon and apricot
Dainty	Light pink	Orange Pink	Orange-pink
		Salmon Pink	Salmon rose

Effect of Temperature on Forcing Lilies. (Harold E. White, Waltham.) A rooting temperature of 60° F. has been found to be more favorable than a temperature of 50° F. for *Lilium longiflorum* var. *giganteum*. This observation has been substantiated over a period of two years. In 1937-38 the number of flowers per plant averaged 5.10 for bulbs rooted at 60° F., compared with 3.79 for bulbs rooted at 50°. A portion of the same case of bulbs, held in cold storage until January 3, 1938, then potted and placed in 60° F. temperature, averaged 3.43 flowers per plant. Heavy watering of the soil during the rooting period did not noticeably affect growth or flowering. A covering of hay over the bulbs on the bench had neither favorable nor unfavorable effect.

Weekly records on the growth of the plants indicated that there was a stage of rapid vegetative growth up to the 12th or 13th week, followed by a period of retarded growth for 3 to 4 weeks. At the end of the 14th to 16th week, another stage of elongation in growth occurred. It would appear that this slowing down in growth took place at the time of bud formation.

Effect of Plant Nutrients, Soil Reaction, and Light on Gardenias. (Harold E. White, Waltham.) The use of fertilizers containing sodium nitrate as a source of nitrogen resulted in an average production of 19.13 blooms per plant and 22.64 percent bud drop. Similar fertilizers with nitrogen in the form of ammonium sulfate gave 22.91 blooms per plant and 18.50 percent bud drop. The fertilizer which gave the most favorable results supplied all nitrogen and phosphorus in organic forms and produced 23.12 blooms per plant with only 14.60 percent bud drop.

The quantity of fertilizer applied per 100 square feet of bench area varied from 2 to 4 pounds, and the number of applications from 2 to 6 per year. When the quantity and the frequency of application of fertilizers containing nitrate of soda were increased, flower production was reduced and bud drop increased. Comparative applications of fertilizers with ammonium sulfate or organic materials as sources of nitrogen did not decrease flower production or increase bud drop as did sodium nitrate fertilizers. This difference in effect on production and bud drop would appear to be due to the availability and accumulation of nitrate nitrogen in the soil from the sodium nitrate.

This opinion is further substantiated by the fact that the total bud drop for the season was reduced to between 2.0 and 2.5 percent on a number of plants by withholding fertilizers until November and December. At that time the plants showed symptoms of nitrogen deficiency with a good set of buds but no development. One group of plants received two applications of a chemical fertilizer. The plants fed with organic materials produced 16 flowers per plant with only 2.33 percent bud drop, whereas those plants receiving chemical fertilizers produced 27 blooms per plant with 2.13 percent bud drop. Bud drop was proportionally as high on nitrogen-deficient plants during November, December, and January as on plants fed more heavily with fertilizers, indicating that soil fertility is not the only limiting cultural factor concerned in loss of buds from gardenia plants.

Further observations on the use of chemical fertilizers containing sodium or calcium nitrate show that symptoms of iron chlorosis on gardenias are intensified as the quantity and the frequency of application of fertilizers are increased. Fertilizers with ammonia and organic forms of nitrogen, when applied in the same quantity and frequency as the calcium or sodium nitrate mixtures, did not cause chlorosis. One-year-old plants grown for a second season are chlorotic or normal depending upon type of fertilizer treatment of the soils.

Monthly pH determinations have been made on gardenia soils under different fertilizer conditions. The data, compiled from records for two years, show no relation between degree of acidity and severity of chlorotic symptoms of gardenia plants.

On the basis of experimental results it is concluded that chlorosis caused by the inactivation of iron can be prevented under commercial cultural conditions through the use of soils relatively low in nitrate nitrogen, and by the judicious application of fertilizers so as to limit the accumulation of nitrate salts in the soil.

Detailed results of experimental work with gardenias were published in the *Proceedings of the American Society for Horticultural Science*, 1937.

Propagation Studies with Geraniums. (Harold E. White, Waltham.) The use of fungicides on geranium stock plants in the field as a means of producing disease-free cuttings proved to be of little value. A 2-2-50 and a 4-4-50 Bordeaux mixture and a 4-50 wettable sulfur spray were applied twice in June, July, and August, and once in September. Moderate to severe burning of the foliage resulted from the use of all these materials and the rooting of cuttings was not increased very appreciably.

Cuttings taken from stock plants grown in greenhouse benches rooted consistently better with less loss from stem rot than cuttings taken from field-grown plants. An average of 9 cuttings per plant was obtained on inside bench-grown stock as compared with an average of 3 cuttings on field plants. The excellent results of propagation from greenhouse-grown plants as compared with field-grown plants have been consistent over a period of two years and demonstrate definitely that the best insurance against losses from stem rot and for increasing the percentage of rooting is to grow geranium stock plants under glass.

The results obtained by treating geranium cuttings with a synthetic growth substance in powder form were very satisfactory. While such treatments did not appreciably reduce losses from stem-rot disease, a much higher percentage of treated cuttings rooted. Roots were much more abundant on treated cuttings than on the checks.

Cuttings from geranium plants at Waltham were taken to a local commercial greenhouse for rooting, to determine whether management of the propagation houses and conditions therein were important. On the same date cuttings were taken from this grower's inside pot-grown plants and from his field plants, for rooting at Waltham. None of the plants had been sprayed. Irrespective of conditions in the propagating house at Waltham or the commercial greenhouse, cuttings from inside-grown plants rooted better than those from field-grown plants.

Geranium cuttings from inside-grown plants gave a high percentage of rooting in 2¼ inch pots of soil, whereas cuttings taken from field plants rooted very poorly under such conditions.

The use of horticultural wax emulsions as dips for the foliage of geranium cuttings to prevent excess transpiration did not prove successful. Root cuttings of geraniums did not prove satisfactory for propagation, at least under fall conditions; however, root cuttings made in the spring when the plants are in an active state of growth may give better results.

A report in detail of propagation work with geraniums was published in the *Proceedings of the American Society for Horticultural Science*, 1937.

Packet Seed Studies. (Clark L. Thayer.) For a third season the Department of Floriculture has cooperated with the Seed Laboratory in a study to determine the quality of flower seed sold in retail seed stores and in various other types of retail outlets. The seeds which were collected by state inspectors were weighed and analyzed for purity in the laboratory and were tested for germination and trueness to type under field conditions.

A total of 175 lots comprising 36 different kinds of flowers and packeted by 28 wholesalers was included in the tests. Records on germination in the field showed the following results: 113 lots, good; 43 lots, fair; 13 lots, poor; 6 lots, no germination. Complete records on trueness to type were not obtained because of extremely adverse seasonal conditions; 97 lots gave satisfactory results, 2 lots were fair, 17 were not satisfactory, and for 59 lots the records were incomplete. Detailed results are included in Bulletin No. 96 Control Series, Massachusetts Agricultural Experiment Station.

DEPARTMENT OF HOME ECONOMICS NUTRITION

Helen S. Mitchell in Charge

Cause and Control of Nutritional Cataract. (H. S. Mitchell, G. M. Cook, and O. A. Merriam.) Human cataract is a degenerative change in the lens which causes it to become opaque with gradual blurring and final loss of vision. Surgical removal of the lens and the proper correction by a glass lens restores only a portion of normal vision. There is no effective therapeutic agent for the prevention or cure of cataract, nor does medical science know its cause.

The experimental induction of cataract in rats is a step forward, and allows this pathologic change to be studied under carefully controlled conditions. It is hoped that the results of animal research may ultimately suggest some clinical applications. That cataract could be produced in rats by feeding a diet adequate in every respect, but supplemented with galactose, was discovered in 1935. Apparently no vitamin or mineral deficiency is involved, but there is some metabolic disturbance as yet unsolved. This method of producing cataract in a few weeks without other apparent injury to the rat is being used to study the influence which other dietary factors may have upon lenticular changes. A paper on the subject was given before the New England Ophthalmological Society, December 21, 1937. A popular review was broadcast from Station WAAB over the Colonial Network, January 28, 1938, under the auspices of the American Chemical Society.

1. *Factors Influencing Progressive and Regressive Changes.* During the several years of work on cataract, data on the progressive morphologic changes in the lens were recorded. A careful study of these data revealed certain consistent findings which might be of particular interest to the ophthalmologist. In rats fed on the galactose rations the lens begins to show, by the fifth day, early changes observed through an ophthalmoscope. A dense shadow appears at the equator of the lens and spreads rapidly over the anterior surface. This film, which appears to have a vacuole or cell-like structure, then disintegrates and disappears before the true opacities of the lens become visible to the naked eye. The visible cataract appears first as a posterior opacity, then becomes nuclear, and finally the entire lens is dead white instead of the clear glassy red of the normal eye. These progressive changes continue even after the rat is returned to a normal ration. There is apparently a lag in the effect of galactose or else a physiologic sequence of events, which, once started, cannot be altered. After several weeks on the normal ration certain regressive changes seem to occur, the complete opacities again becoming nuclear in type. A suggested explanation of this latter phenomenon is that new lens fibers grow around the opaque ones forcing them to the center. The age of the animal and the extent of the injury seem to influence the degree of retrogression. These data plus a review of previous work were published in the *Archives of Ophthal.* 19:22, 1938.

2. *The Effect of the Type and Amount of Protein on the Cataract-Producing Action of Galactose.* It was previously reported that a protein deficiency (5 percent) hastens the development of cataract in rats fed on a diet containing 25 percent galactose. Further work indicates that a high level of protein (45 percent) greatly inhibits the cataractous change in the lens compared with that observed in rats fed the control ration containing 15 percent of protein. The degree of galactemia is not significantly altered by the level of protein ingested. The striking results obtained with rations containing casein led to the use of five other sources of protein: egg albumin, lactalbumin, beef muscle, fish muscle, and soybean meal, fed at comparable levels of 5, 15, and 45 percent protein. The protective action of the crude proteins measured in terms of time and incidence of mature cataract varies to a significant degree, showing egg albumin to be more protective and the others less protective than casein. With a lower level of galactose (15 percent), the influence of the amount of protein in the diet becomes more pronounced. A high incidence of mature cataract develops when 5 percent of protein is fed, early lens changes occur with 15 percent of protein, and complete protection is common with 45 percent of protein. As previously reported, the slight inhibitory effect of cystine upon the cataract-producing action of galactose does not seem to explain the protective effect of proteins. Methionine also exhibits some inhibitory action, but not commensurate with that of protein containing an equivalent amount of this amino acid. The abstract of a paper given

before the American Society of Biological Chemistry, Baltimore, March, 1938, was published in *Proc. Soc. Biol. Chem.* 87, 1938.

3. *Effect of Riboflavin and Thiamin Chloride upon the Cataractogenic Action of Galactose.* While no gross symptoms of vitamin deficiencies have existed at any time, it seemed possible that galactose might create an unusual metabolic demand for certain vitamins. Two crystalline fractions of the vitamin B complex were supplied by Merck & Company for this investigation. Rats fed an adequate ration containing 25 percent galactose showed normal growth and approximately the same incidence of cataract regardless of the amount of extra vitamin supplements. Two groups of rats fed massive doses, 2000 micrograms riboflavin and 2000 micrograms thiamin chloride respectively, showed an incidence of cataract similar to litter-mate controls receiving 50 and 20 micrograms of each. It was concluded from these data that massive doses of riboflavin or thiamin chloride exert no protective action against the development of galactose cataract in rats. This paper was published in *Proc. Soc. Exper. Biol. Med.* 39:325, 1938.

4. *The Influence of Calcium Salts on Lactose Metabolism.* Incidental to the work on lactose and galactose metabolism in rats it was noted that certain calcium salts exerted an inhibitory influence on lactose absorption. Research now in progress is attempting to explain the nature of this inhibitory action and the differences observed between the different salts used.

A Study of the Nutrition of College Women with Respect to Vitamin C Requirements. (H. S. Mitchell and O. A. Merriam. Conducted as a joint project with Rhode Island State College. E. L. Batchelder cooperating.) One of the problems which is a challenge in the field of nutrition today is that of finding a valid approach to an estimation of human vitamin requirements. The estimated intake of vitamin C in food plus the titrated ascorbic acid value of the urine were chosen as the most practicable criteria for the study of vitamin C nutrition on a college campus.

These survey studies were conducted at Massachusetts State College and at Rhode Island State College with 209 freshman women and 40 junior women as subjects. Most of them ate at the respective college cafeterias and records were kept of amount and kind of food consumed for periods of from 8 to 15 days preceding the urinary study. One or two consecutive 24-hour urine collections were made by each girl in the fall and again in the late winter. Ascorbic acid content was determined by a modification of Tillmans' titration method on the acidified, pooled 24-hour specimen.

Ascorbic Acid Excretion in the Urine

Place	Period and Date	Number of Subjects	Ascorbic Acid per 24 Hours	
			Range mg.	Average mg.
	Period 1			
M. S. C.	1936	77	3 to 80	20
M. S. C.	1937	71	8 to 78	22
R. I. S. C.	1937	62	1 to 73	15
	Period 2			
M. S C.	1937	70	7 to 145	33
M. S. C.	1938	61	3 to 106	27
R. I. S. C.	1937	40	2 to 158	28

The ranges and averages of excretion values for the three groups at the same season of the year were strikingly similar. While the averages were within normal limits, fully one half of the subjects in each group were significantly below what has been considered an optimum value. The late winter excretion values were somewhat higher on the average, apparently reflecting an interest in increased use of orange juice and other foods rich in vitamin C. This work was reported in a joint publication entitled: The Vitamin C Status of College Women as Determined by Urinary Excretion. Authors: Helen S. Mitchell, Oreana A. Merriam, and Esther L. Batchelder. *Jour. Home. Ec.* 30:645, 1938.

The Relation of Iodine or other Minerals to the Prevention of Cholesterol-induced Atherosclerosis in Rabbits. (H. S. Mitchell, M. Goldfaden, and G. Hadro.) This research is being sponsored by the Lang Fund. It has been successfully demonstrated that gross pathological lesions of the aorta of rabbits may be produced by feeding cholesterol. When the amount and time of cholesterol feeding is so controlled as to produce moderate aortic lesions, kelp fed in the ration along with the cholesterol may partially or completely protect litter-mate rabbits against these pathologic changes, whereas potassium iodide fails to give this protection. The cholesterol content of the blood of rabbits on these experiments indicates that there is some correlation between the circulating cholesterol and aortic lesions. Growth and general condition of the rabbits have continued satisfactory throughout the experiments. This study is still in progress, with Miss Hadro as assistant. Work completed by May 1938 was reported by Miss Goldfaden in a Master's thesis, June, 1938.

Nutritional Gizzard Lesions in Chicks. (William B. Esselen, Jr.) Gizzard lesions in chicks appear to be caused by a deficiency of the "anti-gizzard-lesion factor" in the diet. The gross pathology is characterized by lesions or eruptions in the lining of the gizzard. Field observations in Massachusetts during the past three years indicate that this condition is of economic importance to the poultrymen of the State. Gizzard lesions have been observed in young chicks fed on commercial chick rations which were thought to be nutritionally adequate. In such cases the deficiency may date back to the parent stock, the eggs from which the chicks were hatched being deficient in the "anti-gizzard-lesion factor."

Investigations were conducted here to observe the development of gizzard lesions in chicks on the gizzard lesion producing diets of Almquist and Stokstad and of Bird, Kline, Elvehjem, and Hart. Studies were also made relative to the ingredients necessary to make up a diet which will prevent gizzard lesions and the ability of certain ingredients commonly used in chick rations to prevent and cure the condition.

The Massachusetts State College chick ration, which was used as a control diet, gave practically complete protection against gizzard lesions. A study was made of the individual components of this ration and of combinations of them, in order to determine why it prevented gizzard lesions. It was found that a mixture of 15 percent each of wheat middlings, wheat bran, and oat groats, and 4 percent of alfalfa leaf meal, added to the Almquist diet, was almost as effective as the Massachusetts State College ration in preventing gizzard lesions. Although in this instance these amounts of the supplementary dietary ingredients effectively controlled gizzard lesions, it must be realized that this may not always be true. It is quite possible that these materials will vary in their content of the "anti-gizzard-lesion factor" depending upon their source, storage conditions, and previous history. Also it is very probable that chicks from different sources will vary in their susceptibility to gizzard lesions.

The experimental evidence obtained points to the fact that there is no correlation between rate of chick growth and the severity of gizzard lesions.

The curative studies showed that dried pork lung, alfalfa leaf meal, soybean meal, oat groats, and wheat middlings were all effective, at least to some degree, n curing gizzard lesions. Of these the alfalfa leaf meal appeared to be the most effective at the levels fed. The Massachusetts State College ration, which was effective in preventing gizzard lesions, was likewise a very good curative agent.

It was demonstrated that chicks kept for one or two weeks on a diet which prevented gizzard lesions, soon developed lesions when changed to the Almquist gizzard lesion producing diet. These findings provide further evidence that chicks do not store any great amount of the "anti-gizzard-lesion factor" in their body and that they do need a constant source of this factor in their diet.

A preliminary study with turkey poults indicated that young turkeys either are not susceptible to nutritional gizzard lesions or are more resistant to them than are chicks.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Technological Investigations on Apples. (C. R. Fellers, J. A. Clague, and A. S. Levine.) The canning experiments on baked and glazed apples were continued with 20 varieties. Among the best for canning are Northern Spy, Baldwin, York, Rhode Island Greening and Gravenstein. Glazing in syrup is preferred to actually baking in an oven. A 40° Brix syrup is recommended. The canned product is very attractive, of excellent flavor, and keeps indefinitely under good storage conditions. The addition of small amounts of malic or citric acid to the syrup materially improves the final product.

The canning of apple slices in syrup is now being investigated. By cooking slowly in boiling syrup, or by vacuumization, the gases are removed from the tissues. Whether or not canned sliced apples in syrup will prove to be a good dessert fruit cannot be anticipated. We feel that the possibilities are bright.

Apple pectin extracts have been manufactured experimentally with a view to obtaining a stable, home-prepared yet effective, jellying agent. The varying of the hydrogen-ion concentration of the extracting medium produced marked differences in pectin yield, sugar strength, and jelly strength of the pectin extracts. An increase in hydrogen-ion concentration increased pectin yield and sugar supporting capacity of the extract. Exposure of the sliced fruit to air before extraction was inimical to the sugar strength of liquid apple pectin. The longer the exposure, the greater became the destructive pectinase enzyme action. Storage of the extracts at high temperatures resulted in a loss in viscosity and sugar strength. The use of Clarase and diastase preparations effectively cleared apple pectin extracts from starchy suspensions. In most cases pectin quality was injured to some extent by the use of clarifying enzymes.

Vitamin C determinations were made on 30 additional varieties of apples during the harvesting season. As previously reported, extreme variations in vitamin C content occur among varieties.

Nutritive Studies on Fresh and Processed Fruits and Vegetables. (C. R. Fellers, Wm. B. Esselen, Jr., W. A. Maclinn, and C. F. Dunker.) The vitamin C investigations on raw tomatoes and processed juice have been continued for the third successive season. Since the results are being published in full in Bulletin 354, they are not discussed here.

Additional work on spinach showed that fresh, raw spinach contains from 400 to 450 international units of vitamin C per ounce. The loss on cooking was from 33 to 67 percent depending on the amount of cook water used; in general, the larger the amount of water, the greater the loss. From 10 to 30 percent of the original vitamin C in the spinach could be recovered from the cook water. Freezing and incidental operations caused a loss of about 45 percent of the vitamin C, and canning 60 to 65 percent. Dehydration of spinach resulted in total destruction of vitamin C.

Dehydroascorbic acid was not found in either raw, frozen or canned spinach. Iodine titration values for ascorbic acid averaged 19 percent higher than the indophenol values. Satisfactory checks were obtained on both raw and cooked spinach by the indophenol dye titration and animal bioassay methods.

In a study made to determine the effect on vitamins B_1 and B_2 (G) of freezing and canning vegetables, work has been completed on asparagus, peas, lima beans, and spinach with the following results:

Vegetable	Raw Vegetables International Units per Gram		Percentage Retained— On Freezing		Percentage Retained— On Canning	
	B_1	B_2	B_1	B_2	B_1	B_2
Asparagus	0.66	0.48	74	95	71	78
Peas	1.48	0.61	97	100	66	100
Lima Beans	0.65	1.09	46	84	25	73
Spinach	0.4	1.54	92	91	87	38

Thus, generally speaking, both frozen and canned vegetables are good sources of both vitamins B_1 and B_2.

Extreme variations were shown in ascorbic acid content of fresh spinach, peas, and other vegetables as delivered to the Boston market throughout the year. Massachusetts-grown spinach varied from .14 to .47 milligrams of ascorbic acid per gram and was no higher in ascorbic acid than shipped-in spinach from Texas or Virginia. The same holds true for most other vegetables. The average values for fresh vegetables when cooked were approximately the same as for the frozen product.

Freezing and canning processes were only slightly destructive to the carotene content of vegetables. For the maximum retention of both ascorbic acid and carotene in fresh or frozen fruits and vegetables, precautions must be taken to avoid exposure and oxidation.

A method for the estimation of carotene in green vegetables has been published (*Proc. Am. Soc. Hort. Sci.* 52, 728-733.) In spinach, the mean ratio of vitamin A potency (in international units per gram, as determined by the rat assay) to carotene content (in micrograms per gram) was 1.7. By using the above value, fresh, frozen, canned, and dehydrated spinach contained, respectively, 718, 545, 481 and 495 international units of vitamin A per gram. Storage of canned and frozen spinach for several months had no effect on its vitamin A content.

Possible Nutritional Aspects of Arthritis. (Wm. B. Esselen, Jr. and C. R. Fellers.) In this research project, conducted under the Lang Fund, it was previously found that iodine, kelp, and vitamins B_1, B_2 (G), and D in the diets of guinea pigs had no effect on the development or the pathology of scurvy.

This study has been continued with an investigation on the curing of scurvy in guinea pigs. Guinea pigs were kept on a vitamin C-free ration until scurvy had developed; then fed optimal amounts (10.0 mgm.) of vitamin C daily. In addition to the vitamin C treatment some of the groups of animals were fed 10,000 international units of vitamin D daily, or received 10 percent of dried yeast in their ration as a source of vitamins B_1 and B_2 (G). The results indicate that relatively large amounts of vitamins B_1 and B_2 (G), in addition to optimal amounts of vitamin C, in the diet of scorbutic guinea pigs were of value in hastening their recovery from scurvy.

Bone ash studies made on the animals used in the above investigation showed that the ash content of guinea pig femurs decreased from 60 to 70 percent down to 35 to 40 percent in severe scurvy. As the scurvy was gradually cured, the ash content of the bone increased. This increase in the ash content of the bones tended to vary directly with the rate of recovery. Vitamin D did not appear to have any marked effect on the ash content of guinea pig femurs either during the development or during the cure of scurvy.

Preservative Effects of Acetic and Benzoic Acids. (A. S. Levine, M. G. O'Connor, and C. R. Fellers.) Investigations have been started to determine the specific effects of benzoic acid and acetic acid (vinegar) on bacteria, yeast, and molds as related to food and beverage preservation. The antiseptic property of acetic acid may be due not to hydrogen-ion concentration alone but also to the undissociated molecule. This acid is, in itself, bactericidal and enhances the preservative property of sugar and salt. It also decreases the processing time required for canning products to which it is added.

Benzoic acid and benzoate salts have long been used as food and beverage preservatives. The mechanics of the preservative action is under investigation. These salts act with much greater effectiveness at pH values below 5.6 than above this point and approaching neutrality. The storage life of haddock and cod fillets was greatly increased by dipping in a 5 percent salt brine containing from .15 to .3 percent sodium or magnesium benzoate. The use of benzoated ice for icing round fish materially improved keeping quality. The use of benzoate in foods is legal but must be declared on the shipping containers.

Cranberry Research. (C. R. Fellers, A. S. Levine, and Wm. B. Esselen, Jr.) Cooperative cranberry storage experiments have been conducted for the third and last year. Carbon dioxide-oxygen ratios were determined on monthly samples of Early Black and Howes cranberries stored at 35°, 45°, 55°, and 60° F. The two lower temperatures were again superior for storage of ripe or semi-ripe berries.

Cranberry sauce packed with a dextrose-sucrose ratio of 1:3 had a better flavor as determined by judging experiments than did the 100 percent sucrose or the 1:1 ratio pack. Tests were conducted monthly for five months with the above results.

Two new products have been investigated for development: cranberry relish, a pleasing combination of cranberries, oranges, and sugar preserved with 5 percent alcohol; and cranberry wine, the fermentation product of cranberry juice reinforced with the deficient elements necessary for yeast activity.

The manufacture of cranberry juice has been described in a paper published in the *Fruit Products Journal*, Vol. 18, No. 7, 1939. This is the first published article on cranberry juice and is a result of studies extending over a period of five years.

Studies on experimental and commercial packs of canned cranberry sauce show that the approximate amount of decayed fruit used in making the sauce can be determined by means of a microscopic examination of the sauce. The test consists in ascertaining the percentage of microscopic fields showing the presence of mold filaments. The presence of mold in more than 50 percent of the fields indicates that an excessive amount of decayed fruit was used in the sauce. Quantitative aspects of this problem are now under study so that the information may be available to the cranberry packers before the 1939 season.

Studies of immature, half-colored, and fully ripe cranberries show that there is no appreciable increase in vitamin C content with advancing maturity.

Hemoglobin regeneration tests with anemic albino rats showed that the iron of cranberries was fairly well utilized in the regeneration of the red blood cells.

Fresh cranberries contained about one international unit per gram of vitamin A, no vitamin B_1, and approximately 0.15 Bourquin-Sherman units per gram of vitamin B_2 (G).

Currant Juice and Jelly. (Julius Novick and C. R. Fellers.) Currant juice has a pH of 3.45 and contains approximately 2.04 percent citric acid, .46 percent pectin, and 7.5 percent soluble solids. The fresh currants and juice, which are high in vitamin C (180 international units per ounce), also contain considerable carotene. Two short extractions in boiling water produced the most satisfactory juice for jelly making. The optimum acid concentration in currant water extract was from .3 to .5 percent. Excess acidity resulted in decreased viscosity and jelly yields. Diastatic enzymes did not aid in clarifying the juice. The concentration of juice prior to the addition of sugar definitely decomposed the pectin, while sugar added at the start had no detrimental effect.

Suitability of Dextrose as a Food Ingredient. (C. R. Fellers and A. S. Levine.) Laboratory work has been extended to include canned fruits and vegetables, jams, preserves, jellies, marmalades, fruit butters, soda fountain crushed fruits and syrups, sweet pickles, and apple sauce. In general, from 20 to 33 percent of the total added sugar may be in the form of dextrose. Because of crystallization, the concentration of dextrose in fruit products must be under about 40 percent. Improvement in quality resulted in some products containing dextrose in place of a part of the sucrose. A material saving in cost can be effected by using dextrose in place of sucrose in foods. A paper appeared in the *Am. Jour. Public Health* for February, 1939, on the use of dextrose in the food industries and the public health aspects involved.

The Potato as an Anti-scorbutic. (Mary E. Lyons and C. R. Fellers.) Because of its extensive use, the potato is of exceptional nutritional interest. Samples were obtained from 10 potato-growing regions of the United States and compared as to their content of vitamin C. No significant geographic variations in vitamin C content were found. The average value of 87 international units per ounce for the raw potato is just about equal to that of canned tomato juice. In eight varieties the average loss in vitamin C during baking was 49 percent and in boiling whole in the skin 37 percent. There was no correlation between size or maturity of tuber and vitamin C content. By far the greatest concentration of vitamin C in the baked potato is in the central core area.

DEPARTMENT OF HORTICULTURE

R. A. Van Meter in Charge

Horticultural Value and Culture of Perennial Asters. (Ray M. Koon, Waltham.) Four hundred and twelve species and varieties of Asters have been observed and evaluated as excellent, good, fair, or "of no horticultural value." Of these, 92 rate as excellent and 74 as good; the others have little merit except for naturalizing or hybridizing. Many collected from other states and from abroad fail even to equal their relatives growing wild in our fields and along our highways.

Of those ranking as excellent, the following are recommended for the May-to-October garden in Massachusetts:

Star of Eisenach (*A. subcaeruleus*)
Wonder of Stafa (*A. Thomsoni*)
King George (*A. amellus*)
General Pershing (*A. amellus*)
Silver Spray (*A. cordifolius*)
Harrington's Pink (*A. novae-angliae*)
Mr. Everest (*A. novi-belgii*)
Dr. Eckner (*A. novae-angliae*)
Mt. Rainer (*A. novae-angliae*)
Charles Wilson (*A. novi-belgii*)
Skylands Queen (*A. novi-belgii*)
Helen Durward (*A. laevis*)
Remembrance (*A. novi-belgii*)
Campbell's Pink (*A. oblongifolius*)
Burbank's Charming (hybrid of unidentified parentage)

A form of the rather rare white *novae-angliae* sent by an amateur in Washington State to Waltham for trial proved superior to the type and has been named Mt. Rainier by the investigator. This Aster was shown at Horticultural Hall and received the Award of Merit of the Massachusetts Horticultural Society.

By popular acclaim the most attractive fall-blooming Aster in the collection was Harrington's Pink, a *novae-angliae* discovered in a small nursery in Cedar Point, Iowa. It is the only true pink Aster in cultivation and promptly received the Award of Merit of the Massachusetts Horticultural Society. This variety has been crossed with several others in an attempt to produce some clear pink dwarfs of which none exists at present.

The long stalks of such varieties as Dr. Eckner, Ryecroft Purple, Red Cloud, and certain others are unattractive. It was found that these plants, which usually grow to six feet, can be pinched back advantageously June 1 and again July 1, reducing the height and greatly improving the appearance.

If exhibition plants of *novae-angliae* and *novi-belgii* are desired, only one shoot from a clump should be allowed to grow.

Amellus varieties, of which King George, Rudolph Goethe, and Jacqueline Genebrier are examples, flowered best as two-year-old plants. On the other hand, the *novi-belgii* group, which have given more garden varieties than any other species, should be divided each year.

With the exception of *subcaeruleus* and *alpinus*, which should be planted in the spring, it made little difference whether Asters were set out in April or September. Planting after growth is well started in mid-May will result in stunting. October planting does not allow plants sufficient time to establish themselves before freezing weather. Many varieties will survive after delayed autumn planting but it is a practice uncertain of success.

Carl Frikart's splendid Aster, Wonder of Stafa (Switzerland), a seedling of *Thomsoni*, has failed to survive at Waltham three winters out of five.

Attempts to cross several species and varieties have resulted in very few viable seeds. Most of the popular named hybrids are sterile.

Clematis Propagation. (George Graves, Waltham.) Whole-stem, summer-made internodal cuttings from potted plants of various hybrid varieties indoors showed considerable variation in rooting time. This variation was due, apparently, to age and time of cuttings, or to auxin treatment at time of making. Rooting media, humidity, and moisture control or other cultural particulars were applied generally and cannot be looked to for variables.

Since single-node internodal Clematis cuttings are awkward to handle, auxin was applied in dust form (talc or charcoal impregnated with naphthalacetic, indoleacetic, or indolebutyric acids) to bases of individual cuttings. Results in these beginning tests were mixed. On the whole, talc seemed to be a better carrier than charcoal. Easy-rooting varieties such as Mme. Edouard Andre or Countess de Bouchard were much accelerated in rooting by auxin treatment. On the other hand, some of the stem-rooting varieties which do not seem to root at the extremity of the cutting did not show such speeding up. In fact, check cuttings of the variety Belle of Woking rooted before those which were auxin treated, although this last condition may have been caused by other factors.

With all varieties tested, a high percentage of successful rooting was accomplished without application of auxin.

Delphinium Propagation. (George Graves, Waltham.) The work thus far has been a rechecking under local conditions of European practices and of this investigator's own published reports on the subject.

This recheck has determined the commercial feasibility of vegetative increase of healthy and worthwhile Delphiniums by four methods of procedure:

1. Cuttings taken indoors during late winter or very early spring for potted stools carried at a temperature of 50° F.
2. Cuttings taken from outdoor plants in late March.
3. Scantily rooted bases of flowering stems potted and treated as cuttings just after first flowering.
4. Outdoor division of the stool.

In general, cuttings are new shoots pulled off with heels while still but a few inches high. Cuttings and poorly rooted divisions are best handled in individual pots in sandy soil or a mixture of half soil and half sand. Fifty degrees Fahrenheit (50° F.) is an ideal temperature for all operations connected with the propagation of Delphiniums from cuttings.

The use of healthy stock plants, hot water treatment for mites, and protection against cutworms at planting time are all important in the propagating program.

Beach Plum. (George Graves, Waltham.) Roots of four clones of Beach plum (*Prunus maritima*), selected for season or quality of fruiting, were sent in from Martha's Vineyard by Mrs. Wilfred O. White, Newton Center, Mass.

From observation of the behavior of this material, it has been confirmed that individual clones of Beach plum may be propagated in frames or in the open by the simple process of planting segments of sizable roots either with apical end down and basal end at soil surface, or by shallow horizontal planting.

Also, propagation by cuttings has been found both possible and practical. This method, however, requires more knowledge of the processes of vegetative propagating technique.

Propagation by grafting or budding would seem to be unnecessary, unsatisfactory, and illogical.

Study of Hardy Ornamental Plant Material. (Harold S. Tiffany, Waltham.) Each year selection and hybridization are producing types and forms in the plant world distinctly in advance of their predecessors. A study of the trade catalogues of herbaceous perennials reveals a need for the inclusion of many of the newer sorts in place of certain old standard varieties. Much as he may desire to, the nurseryman often finds it difficult or impractical to acquire from the Bureau of Plant Industry, to import from abroad, and to test on his own grounds plants of uncertain value. There had been no organized study of such material in this region previous to the establishment of the plant trials at Waltham. This collection is proving of great value to the commercial plant grower and to the public directly who have convenient access to the plantings.

The testing of 1551 species and varieties of herbaceous ornamentals has shown that certain ones are definitely unsuited to this climate because of tenderness and that others are unworthy because they possess comparatively little garden value. The factors of (1) hardiness, (2) quality and duration of bloom, (3) comparative vitality, (4) susceptibility to pests, and (5) propagation methods constitute the basis on which garden value has been determined.

At intervals, the Nurseryculture Bulletin is sent to some 300 nurserymen in this state to acquaint them with the results of these investigations.

This year 1140 accessions have been added to the collection making a total of 2485, a sufficiently comprehensive number from which definite recommendations as to their rating will be made.

Intensive study has been given to 8 varieties of Aubrieta, 31 varieties of Delphinium, 35 varieties of Heuchera, 31 varieties of Dwarf Iris, 72 varieties of Lilium, 40 varieties of Papaver orientale, and 38 varieties of Tulipa (species). As evidence of the merits and faults of the various members of these groups is obtained, their ratings which have previously been undefined are becoming established.

DEPARTMENT OF OLERICULTURE

Grant B. Snyder in Charge

Shape Index Studies of Tomatoes. (W. H. Lachman.) Studies in previous years indicated that shape indices were quite reliable for making quantitative comparisons among varieties of tomatoes. Shape indices, therefore, would appear to be a valuable tool where satisfactory comparisons of varieties are necessary and to ascertain whether progress is being achieved in type improvement during the course of a tomato breeding project.

These studies have been continued and have been made to include the effect of soil variability upon the shape of tomato fruits as well as climatic influences on the modification of form. Yield records also have been obtained in an effort to determine how large the yield differences among varieties must be in order to be significant.

On the basis of the records of one year, a difference in yield of 30 percent was found necessary to indicate significance.

Sweet Corn Breeding. (W. H. Lachman.) More than 1600 plants of eight varieties of sweet corn have been inbred in an effort to isolate pure lines which excel in uniformity of earliness, productivity, disease resistance, and quality. Two hundred of these inbreds show a moderate to high degree of resistance to bacterial wilt as well as freedom from lodging during the period of maturity.

Soil Preparation for Vegetables. (W. H. Lachman and G. B. Snyder.) Tillage methods prior to seeding or plant setting in the field is considered important by vegetable growers. During the past summer a comparison was made between normal tillage and rotary tillage, to study their relative merits in the incorporation of organic matter in the soil and their influence upon availability of nutrients as well as upon yield and quality of several vegetables. Abnormal weather conditions during the summer appear to have masked any significant differences which might have been displayed during a normal growing season.

Tomato Breeding. (W. H. Lachman.) Most commercial varieties of tomatoes have a green to yellow-red coloration of the shoulders when firm ripe. This character is undesirable from both the fresh market and can-house viewpoint.

Genetical studies involving several uniform ripening strains and four commercial varieties of tomatoes have been carried to the second generation. The selections made, while all determinate in growth, are very promising in combining earliness, yield, quality, and uniform ripening.

Cultural Practices Prior to Field Setting as Influencing Yield and Quality of Peppers. (W. H. Lachman.) The yield of early peppers is of vital importance to the market gardener. Methods of handling plants prior to field setting were studied in order to observe their effect on earliness, yield, and quality of the fruits produced.

Five lots of Waltham Beauty plants were grown and treated as follows: Light added from 5 to 11 p. m., phosphorus added, dextrose added, plants potted in 4-inch pots, plants blocked out in flats 10 days prior to field setting. Each treatment was replicated five times.

Three pickings were made before August 1. The plants grown in pots were more vigorous and produced 50 percent more fruit by weight than those of any other treatment. The fruit was of good size and quality.

Asparagus Investigations. (Robert E. Young, Waltham.)

Varietal Improvement. Individual yield records for 278 selected asparagus plants have been kept for the past 6 years. The yields of these as a group vary from year to year. This last year the yields were very low, and this condition seemed to exist throughout the State, for commercial growers reported poor crops. The reason for the reduced yields over a large area was apparently unfavorable weather. At Boston, the weather records indicate that the temperature for May was slightly below normal and for June was very slightly above normal. The rainfall for both months was considerably above normal, and this excess rainfall no doubt retarded development of the asparagus buds by keeping the soil cold. These buds developed after the harvest season and produced a larger number of summer stalks than normal. The increased summer growth was an indication that reserve food was in the asparagus crowns but was not used up because of unfavorable weather conditions.

From the yield records of these plants certain ones were selected for parents. Seed from high-yielding plants was planted in 1936 and the crowns set out in 1937. While yield records will not be taken until next season, considerable difference in vigor was noted in the summer growth. There was a surprisingly small difference in the number of stalks produced the year the plants were set out compared with the second year of growth.

The order of growth of these strains from highest to lowest is the same as the average of yields produced by the two parents, and it is hoped that this relationship will continue in the yield records. If the growth-yield relationships are the same for young plants as they have been proved to be for plants of harvesting age, several of the new strains should be a definite improvement in asparagus varieties. It will require several more years of breeding work to obtain the desirable characteristics in an improved variety of asparagus. However, this work may be hastened by asexual propagation.

Depth of Planting and Height of Cutting. This is the ninth year of this experiment, which was designed to determine how the harvesting of spears of varying lengths of green would affect the yield and life of an asparagus planting. The yields this year are the lowest that have been obtained in this experiment.

In a year of low yields the height at which the spear was cut did not affect the yields any differently than in previous years of good yields. From the standpoint of the asparagus grower, maximum yields may be obtained by allowing the spear to grow to 8 inches and cutting 1 inch below the soil, thus producing a 9-inch bunch with 8 inches of green.

In the depth-of-planting experiment the yields this year show that where the soil is kept cold during most of the harvest period by excessive rainfall, the shallow-planted asparagus will produce considerably more than the deeper-planted crown.

Trellis Tomato Experiments. (Robert E. Young and Paul W. Dempsey, Waltham; Alden P. Tuttle, Amherst.) This is the third year of this experiment designed to determine which of the many cultural and fertilizer practices used by growers produce the best and earliest yields. Work is being conducted both at Waltham and at Amherst. The heavy rains during July flooded the plots at Amherst, killing some of the plants and practically destroying the experiment. At Waltham the damage was not so severe but there was a general reduction of growth and vigor over all plots. The hurricane prevented completion of the harvest records.

It was apparent that if plants did not have the fruit formed before the heavy rains they were unable to set and mature fruit after the weather improved.

In general, the treatments that produced the best early yields also produced the best total yields. The value of commercial fertilizer was shown this year in that the plots which received manure but no fertilizer produced only about half as much fruit as plots receiving manure and one ton of 5-8-7 fertilizer per acre.

In previous years, the plants not staked were low in early yield but produced almost as much fruit for the season as did the staked plants. This year, the wet weather apparently affected the plants on the ground more than those staked, because the early yields for the flat-culture plants were about one-third those of the staked plants, and the total yield about one-half.

The highest yield was from plants that had been potted and trained to a single stem, largely because there are almost twice as many plants per acre when they are trained in this manner. However, where land is scarce or expensive, the training of plants to a single stem instead of the usual two would increase the income per acre considerably.

The plots that received no fertilizer, and the plot where the plants were not staked, produced outstandingly low yields. There was a heavy set of fruit on some plots and almost none on others when the storm blew the fruit off the vines.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.)

Lettuce, New York Type. (In cooperation with United States Department of Agriculture.) This past season was very good for lettuce, and practically all varieties headed well. The percentage of heads cut in growers' fields was from 25 to 100 percent better than in normal years.

While it was a good year for the gowers, it was unsatisfactory for breeding lettuce because almost all the strains headed well. The New York 12 strain in the trials headed approximately 40 percent better than during the last two years. The records indicate that in years of good weather New York 12 heads at least as well as any other commercial strain, but when the weather is a little adverse it is one of the first strains to show a reduction in the percentage of marketable heads.

Imperial 44, developed in California by the United States Department of Agriculture, was tried. On the fairly heavy soils at Waltham it headed excellently and was of fair size. Some of the same plants in trials on a light sandy soil in Dighton headed only fairly well, and were too small to be salable.

Trials conducted on a commercial lettuce grower's farm in Dighton, in the center of the most intensive lettuce section, have shown that there is considerable difference in behavior of strains as compared with those grown at Waltham.

Varieties New York 12 and 15 are still recommended for growers' use. Imperial 847 and 44 are certainly worth a trial.

Greenhouse Lettuce. The supply of stock seed of Bel-May lettuce was replenished. The work with the hybrid material under way for the past few years has been continued, but much purification remains to be done before a satisfactory lettuce can be obtained. The quantity of greenhouse lettuce grown for the Boston Market remains about the same.

Celery. The varietal improvement work with celery has been with the early green type. Seed obtained from small growers in another section of the country seemed to be well adapted to our soil, climate, and market. The most important improvement needed in this strain is uniformity of height, and to obtain a more uniform strain 75 single plant selections have been made.

To test the desirability of this celery, which has been named Summer Pascal, samples were sent to growers who asked for them. The results of these trials have been very gratifying. Summer Pascal seems to be a celery that may be grown early and late, can be bleached with paper, and gives the consumer celery of pascal quality. It requires about two weeks longer than white celery to bleach. It has very thick-meated stalks which are very smooth on the outside and bleach to creamy white. Although improvements are not completed, samples will be distributed for trial.

Tomatoes. Although the Waltham Forcing Tomato has become the standard variety for greenhouse use, attempts to improve it have continued. The use of this strain as a trellis tomato was almost double what it was last year. Trellis Tomato 22 sent out for trial has been well received by those who have had trouble obtaining good-sized fruits from other strains of Comet.

Breeding for the purpose of producing an earlier strain continued, and has progressed to the point where one strain, named Early Trellis, will be released to growers for trial in 1939. Early Trellis produced almost twice as much early fruit as the best commercial strains of Comet. Tomatoes obtained in the first three pickings are considered early fruit.

In the variety trials this year, the percentage of No. 1 fruit varied from 25 for Earliana and 38 for Marglobe to 70 for Waltham Forcing. The outstanding feature of the Comet strains of tomatoes as compared with other varieties is the high percentage of smooth No. 1 fruits produced.

Rutabaga or Cape Turnips. Extensive trials of growers' and seedsmen's strains of white and yellow rutabagas were conducted at the Field Station and in Bristol, Plymouth, and Barnstable Counties. The White Cape rutabaga, developed on Cape Cod, was superior to the best yellow when grown on the Cape and at the Field Station. In the Plymouth County trials the White Cape strain was the best white variety but two yellow varieties were just as desirable from the standpoint of production. In the Bristol County trials there was not much difference between the best white strain from Cape Cod and the best local strains; it was in this trial that two yellow varieties, Laurentian and Long Island Improved, were so uniform and free from side roots.

At the Field Station five root selections made from White Cape last year were tried. One of these selections was yellow in color but has the foliage and growth of the White Cape; it will be of value to some growers who raise both white and yellow.

One half of each variety plot received borax at the rate of 15 pounds per acre, and the other half was left for check, to determine varietal susceptibility to black heart, the borax deficiency disease. Samples were taken from each plot for the chemical studies on borax deficiency that are being carried on by the Department of Chemistry, Amherst. Because of the rainy season, no black heart occurred in any of the plots except on the Cape, where the percentage was less than 5, too low to determine differences in varieties.

Breeding work on rutabagas will be continued to develop locally adapted strains of white and yellow types which are uniform in shape and free from side roots.

Cucurbita Pepo. Most of the plants in this experiment were so severely damaged by excessive rain and insects during the rainy period that very few mature fruits were obtained, and the work will need to be repeated. One outstanding fact was noted — the way the hybrid material came through the adverse weather and produced a good crop.

Hutchinson Carrot. The Station's supply of stock seed was increased during the past season. Just before a week of rain set in, the carrot seed crop had the heaviest set of bloom ever seen on carrots in the East. Rain prevented pollination of many flowers and the seed crop was only normal.

The work with hybrid carrot material was continued. Considerable hybrid vigor was noted. It will be several years, however, before this hybrid material can be purified and its value determined.

Wyman Crosby Beet. The work of improving the color of this beet was continued and a good crop of seed was produced from last year's selections. More selections were made this season. Slow but steady improvement has been noted in the color of this beet during the last two years.

Waltham Beauty Pepper. Besides maintaining stock seed of this pepper, over fifty hybrid lines, in which the Waltham Beauty is one of the parents, were grown. Several of the hybrids look very promising and it is hoped that an easier picking pepper of the Waltham Beauty type may be offered before long.

Waltham Scarlet Shell Bean. Wider use of this shell bean by growers has been delayed because of a lack of available seed for large plantings. Most growers are reluctant to grow their own seed, and unless facilities for making this bulky crop available to growers on a large scale can be found the project will be dropped.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

The outstanding event of 1938 was the severe windstorm of September 21. Immediately preceded by a record-breaking rainfall of 11.28 inches in three days, which saturated the soil, an 80-mile wind caused much destruction to both trees and crop in the experiment station orchards. More than half the crop was still on the trees and most of it was blown off. Tree damage was mostly through partial uprooting of the trees varying from a small departure from perpendicular to complete prostration. There was some breakage of large branches, especially with Northern Spy. The fall of neighboring forest trees crushed some apple trees. Out of 770 trees mostly of bearing age, 134 were partially or completely blown over and 34 badly broken. Thus about 22 percent of our experimental trees were more or less severely injured by the storm. Some of the injured trees were beyond recovery but most of them were brought back to normal position and held by means of two or three guy wires anchored to "dead men" buried about two feet in the ground. How well they will recover from the breakage and dislocation of the root system remains to be seen. A previous severe windstorm on May 15 blew down many shade trees but caused little damage to our orchards.

The season was one of ample and even excessive rainfall. The set of apples was rather poor but the fruit sized up well. Peach buds survived the winter cold well and the crop was good except on trees badly injured by the "X disease". Other fruits produced well but there was some damage to small fruits from heavy rains during the ripening season.

The Influence of Various Clonal Rootstocks on Apple Varieties. (J. K. Shaw and L. Southwick.) The stool bed of Malling clonal stocks produced a fair growth of rooted stocks which will be cut next spring. Fall cutting seems to be injurious to the bed. The rooted stocks in the nursery were budded quite successfully, the season being one of abundant rainfall. Several hundred clonal stocks were budded to ten different types of ornamental forms of malus with the hope of securing ornamental trees of different sizes suitable for appropriate landscape plantings. The trees for replanting the field occupied by the old Stock and Scion Orchard made good growth and are available for planting in the spring of 1939. Plans are being made to set this orchard according to the newer methods for field experiments.

The cooperative orchards set in the spring of 1937 have been visited and trunk diameter measurements taken. Some of these orchards are doing very well and only a few will probably fail to give worth-while results. The South Amherst orchard made much better growth than in previous years. Whether the more adequate rainfall of the past two seasons is just becoming effective or whether the better growth is due to some other cause is uncertain. The trees were fertilized with Cyanamid about two years ago. While the time of application and amounts seemed conservative, it is possible that this may have had an injurious effect. It seems wise to be very cautious in using Cyanamid on young trees. Soil from this orchard was transferred to pots and variously fertilized, with ample and restricted water supply, using seedling peach trees as indicators. This test gave no clear indication of beneficial effects of fertilizers but did suggest that limited water supply was unfavorable to growth.

A clonal stock orchard of 90 trees planted at the college in the spring of 1937 made excellent growth. The growth of the trees is so far not greatly affected by the stock. Some of the trees were blown over more or less by the hurricane of September 21 and those on some of the dwarfing stocks seemed to suffer more than others on vigorous stocks.

The McIntosh and Wealthy orchard on clonal stocks grew well. The injection of certain fertilizer materials into the soil in the area where the trees are making poor growth was repeated. No distinct benefits are yet evident. The trees in this orchard suffered rather severely in the hurricane, but only six trees were considered to be ruined. It is difficult to be sure of the relation of stock to injury on account of differences in exposure. Trees on their own roots were uprooted more than those in adjoining rows on Malling X and XIII. It is known that many of the own-rooted trees had unsymmetrical root systems when planted. Those on seedling roots suffered more than adjoining rows on Malling XIII and XVI. There is little to suggest that, in this orchard, trees on semi-dwarfing roots were less resistant to the wind than those on vigorous stocks. Trees on semi-dwarfing stock are showing symptoms of middle age, such as lessened height and shoot growth and smaller apples than those on standard stocks. It is believed that semi-dwarf trees will require better cultural conditions than do trees now commonly grown.

Tree Characters of Fruit Varieties. (J. K. Shaw, A. P. French, O. C. Roberts, and L. Southwick.) The usual trip for inspection for trueness to name was made in August and September by the leaders of this project. Eighteen nurseries scattered from New England to Michigan and Virginia were visited. As the demand for certified trees continues, some seven or eight thousand apple trees were certified under the auspices of the Massachusetts Fruit Growers' Association.

In our own nurseries forty-five varieties of cherries, practically all met with in nurseries, were budded on Mahaleb stocks for further variety study. A similar block of red-leaf peach stocks were budded to fifty-four varieties of peaches. Several lots of more or less uncertain identity were also used in an attempt to positively identify the variety. Most of the buds were from trees known to be true and the others will be carefully checked.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) In the spring of 1938 an orchard of 288 selfed seedlings of Oriole was set in a low, cold situation to let nature eliminate the less hardy ones. It is hoped to obtain a few seedlings of outstanding hardiness for use as new varieties or breeding stock. At the same time a block of 240 selfed Elberta trees was planted to increase this population.

Some breeding was done in the spring of 1938 but little more will be done until the present orchard land becomes available for replanting.

On August 2, 1938, the "X disease" of peaches was observed in Massachusetts for the first time by E. M. Stoddard of the Connecticut Agricultural Experiment Station. A few days later it was found in both the college and station peach orchards. Diseased chokecherries, which are always associated with diseased peaches, were found near the orchards and a campaign started to eliminate them.

The tropical hurricane damaged a number of trees both in the college and station orchards. Some of the trees in the college orchard were set up and wired in place. The small trees in the two seedling orchards set in 1938 were set up. Blown-over trees in the other seedling orchards will be removed or severely pruned and left so that one or two more crops can be obtained. Since this storm blew off all fruit remaining on the trees at that time, no data could be obtained on seedlings ripening after the 21st of September. This may have upset some of the genetic ratios of fruit characters.

An extraordinary case of inheritance of foliar glands has been observed in the Gold Drop peach. The glands of this variety are neither typically globose nor typically reniform. They might be described as "indeterminate". Gold Drop when self pollinated gave 25 percent of the seedlings with globose glands and 75 percent with glands like the parent. When one of these globose gland type seedlings was crossed with Elberta, a pure reniform gland type, the offspring all had glands of the "indeterminate" type.

The inheritance of blossom size appears to follow a simple Mendelian formula. Champion when selfed, gave 128 seedlings with large flowers, 268 with medium, and 129 with small flowers, an excellent fit for a 1:2:1 ratio. Some other combinations gave peculiar ratios which have not as yet been explained.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) Certain changes in the fertilizer treatments of several plots were made in the spring of 1938 to see if any changes in trends will appear in the behavior of the trees. Plot 2, a sod plot which has had only nitrate of soda, received a complete fertilizer, and plot 4 received potash in addition to nitrogen previously applied. On most plots the amount of nitrogen was somewhat reduced. To plot 3, which has never been fertilized, waste hay at the rate of about two tons per acre was applied. This will be worked into the soil in the spring in an effort to build up organic matter which has been reduced by 17 years of cultivation with very poor cover crops.

Several of the trees in this orchard suffered from the hurricane but all have been replaced with the hope that they will not suffer severely from the injury. The yields were rather low due to a poor set of fruit and possibly loss from the hurricane, though all dropped apples were added to obtain the total yield. It still appears that potash in addition to nitrogen is needed in this orchard, but evidence of the need of added phosphorus is not yet clear.

Comparison of Clover Sod and Grass in a Sod Mulch Orchard. (J. K. Shaw.) The sawdust mulch applied to this orchard has failed to suppress the grass but has resulted in no evident injury to the trees. It appears that much more than the four-inch layer applied is necessary to make a covering that will function effectively. Cost of transportation has prevented the addition of more sawdust.

Comparison of Cultivation and Heavy Mulching for Apples. (J. K. Shaw.) The McIntosh blocks, comprising 18 trees, in this experiment were so badly injured by wind that it seems wise to remove them. The block of Wealthy will be continued for a while. The amount of nitrogen supplied to the cultivated plots was reduced this year and a moderate amount of potash added, because our experience has shown that continued moderate to heavy applications of nitrate of soda bring about an unbalanced condition which may be corrected by supplying potash.

The results from this experiment were reported in Bulletin 328 in 1936. Since then the mulched McIntosh trees have shown somewhat greater trunk growth and the Wealthy exactly the same as the trees in cultivation. Shoot growth on McIntosh 1933-1937 inclusive, a five-year period, was 42.3 inches for the cultivated trees and 45.6 inches for the mulched trees. Yields of the mulched trees have continued larger, especially in the lighter bearing year, than those of the cultivated trees. A heavier crop is picked even with a larger percentage of preharvest drop from the mulched trees. The practice of heavy mulching is increasing among fruit growers. It is a sound practice where it can be carried on at a reasonable cost.

The extraordinarily high nitrate content of the soil under the mulch has been previously reported. High potash has been reported from Ohio, and an examination into conditions in this orchard was therefore made. The test for available potash in the soil by the Morgan and the Thornton tests indicated very high potash under the mulch (over 500 pounds per acre by the Morgan test and over 400 by the Thornton test), and this was true not only of the surface soil but also through the 32-36 inch level. In the cultivated plots available potash was very low or none. The dates of sampling were in May and July. These plots have been heavily mulched with waste hay for fifteen years. In an orchard with plots mulched for five years and others with moderate applications of hen manure, available potash in the plow slice by the Morgan test was 300 pounds per acre on each plot and very low in the subsoil. In a near-by commercial orchard mulched for about five years, it was very low. This suggests that it may take several years for a high amount of potash to accumulate under a mulch. It seems as though soil conditions under the mulch were such as to maintain the soil potash in a more available form than in a cultivated soil.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw.) No changes were made in this project, but it will soon be necessary to remove the trees as they are crowding. The scattered crop of this year had little relation to fertilizer treatment. There is much variability in the growth of the trees on many of the plots indicating that some condition other than fertilization is greatly influencing tree behavior.

Effect of Potash and Lime on Apple trees. (J. K. Shaw.) The trees in this orchard, especially those without nitrogen, have lacked vigor for several years. Tearing up the heavy sod with a harrow proved not very effective and so the orchard was plowed diagonally in the spring of 1938. Cultivation was continued a few weeks and then the plowed area allowed to return to grass. The trees were somewhat invigorated. This practice will be continued. The fertilizer program started in 1927 was continued.

The trees on the nitrogen plots continue to yield better than either those receiving potash or those receiving potash and phosphorus, as would be expected. Those receiving potash in addition to nitrogen yield still better, but there is yet no indication that the complete fertilizer plots yield any better than the nitrogen-potash plots. The study of the effect of lime has been discontinued for some time.

Study of Varieties of Fruits. (J. K. Shaw and staff.) Many new varieties of different fruits were added to our collection and further observations made on those of fruiting age.

During the past year an evaluation of fruit varieties was made by the Horticulturists of the northeastern states. Both old and new varieties were considered. Many old varieties were placed in the discard as having little or no commercial value. These evaluation lists are available in a limited way to those interested.

Apples. Haralson, a comparatively new variety from Minnesota, is of good size and attractive appearance but not of very high quality.

Several new varieties of the Yellow Transparent season have been under observation for several years. One of them, U. S. D. A. 57, has been released for general propagation under the name Close. No. 34 is of the same season, a little earlier than Yellow Transparent, and seems equal or superior to Close under our conditions.

Pears. The Gorham pear has been placed on our list of varieties recommended for commercial planting and Cayuga, Conference, and Phelps on our list for trial.

Plums. Formosa, Stanley, and Albion have been placed on our recommended list and Wrights Early, Santa Rosa, Imperial Epineuse, Hall, and Pacific on our list for trial. Wrights Early is remarkable only for earliness but is the best of its season. Imperial Epineuse is not of attractive appearance but is unexcelled in quality.

Peaches. Halehaven is rapidly replacing South Haven and others of its season. Golden Globe, Golden East, and White Hale are promising new varieties. Golden Jubilee is well established as a major variety and Oriole is gaining in favor. All these except Halehaven were originated at the New Jersey Agricultural Experiment Station. This Station has several new and very promising varieties which should be tested under our conditions. Peach varieties are rapidly changing and only Elberta of the older varieties maintains its position and this may soon be replaced by some superior variety.

Grapes. Erie continues to promise well as an early blue grape to precede Fredonia. Eden is almost a vinifera grape, ripens in midseason, and is of excellent quality. It promises well for home use but is of doubtful commercial value. Urbana and Hanover failed to mature properly even in a late season.

Raspberries. Marcy has thus far been free from mosaic diseases, is of large size and satisfactory in production. It promises to be a valuable variety for us. Taylor suffered seriously from mosaic and apparently will fail to make a place for itself. Newburgh continues to show some mosaic infection and is losing ground though still considered to have some value. Chief and Sodus are the heaviest yielding varieties but have some defects. Sodus is a purple cane.

Strawberries. Catskill still leads in production. It is of attractive appearance and promises to become a standard variety. Pathfinder is a high producer and attractive in appearance but a little soft for some market conditions. North Star (U. S. D. A. 1425) has good quality and size and is a high producer. It is well worthy of trial as a midseason variety. Beauty, Extralate, Fruitland, and Kanner King have proved unsatisfactory under our conditions.

Bud Mutations. (J. K. Shaw and W. H. Thies.) It is realized that the so-called red bud sports may differ from the parent variety and from each other in characters other than fruit color. A start has been made in securing various red mutations of the McIntosh and propagating them for test. Three have been budded on clonal stocks and others will be secured as opportunity offers.

A small branch bearing five highly colored apples was discovered a few years ago in the top of an old Baldwin tree in a station orchard. The general color of the apples on this tree was only mediocre. This has been propagated under the name "Galbraith Baldwin" to see whether the high color is maintained and whether it is a superior strain.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter.) To study the possibility that winter injury might be responsible for continued failure to get a response to differential soil treatments, 24 plots of about 175 plants each were established in the spring of 1937 and fruited during the past year. Six differential mulching treatments were used, each replicated four times:

1. No mulch.
2. Light mulch applied November 12.
3. Light mulch applied December 16.
4. Light mulch November 12, more applied December 16.
5. Heavy mulch applied November 12.
6. Heavy mulch applied December 16.

The crowns of plants in all plots were damaged in varying degrees, suggesting the desirability of applying the mulch earlier. Plots not mulched were damaged most and yielded least. They had, however, the largest number of mature leaves when the fruit was setting, which suggests the desirability of removing the mulch early. A heavy mulch applied early resulted in the least crown damage.

Plots given a light mulch early followed by more at the time of the late application gave highest yields, followed by those receiving a heavy mulch applied early.

In the spring of 1938 a duplicate of this plot arrangement was established with five replications. Five additional plots were mulched heavily with the first cold weather and the mulch will be removed from these plots very early.

Nutrition of the Highbush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) As in previous years chlorotic plants in blueberry Plot D were treated with various chemicals to cure the chlorosis. Again the plants treated with sulfate of ammonia were the only ones to show marked improvement. Plants sprayed with ferrous sulfate, 2 gm. per liter, developed green spots where drops of spray had collected.

Plants growing in three-gallon crocks, treated in 1936 with 40 gm. of lime per crock, all died in 1937; only one of five plants treated with 20 gm. of lime survived. This one plant is slowly recovering under a soil acidification treatment; 10cc. of N/10 H_2SO_4 added from time to time when plants ware watered. Plants receiving 10 gms. and those receiving 5 gms. each of lime are all alive but chlorotic. A 1.0% solution of ferric citrate was injected into the stem of one of these chlorotic plants. The solution was so strong that all the leaves dropped. A new set of leaves formed which had the normal green color. This experiment was repeated with a 0.25% solution of ferric citrate with the same results except that not all the leaves dropped. Chemical analyses of the tops and roots of blueberry plants growing in soil treated with phosphoric acid (H_3PO_4) were made by Mr. J. N. Everson of the Department of Agronomy. These analyses indicated that the occurrence of chlorosis is related to a change in the H-ion concentration of the plant tissue.

During the hurricane of September 21, twelve blueberry plants were blown out of blueberry plot D. These were all of the variety Rubel, were among the largest plants, and were broken off from one to three inches below the surface of the soil. During the heavy rains preceding the hurricane there was a great deal of soil erosion on this same plot. This erosion has rapidly become so serious that it would be unwise to start a fertilizer experiment before the erosion is stopped.

Blueberry Culture. (J. S. Bailey.) Clean cultivation with cover crops has not been a satisfactory method of culture for blueberry plot D where the land slopes from three sides toward the center. Soil erosion is excessive. After the berries are harvested, it is too late to sow buckwheat and get much growth. Barley was tried one year but the catch was spotty and growth poor.

The use of a light one-horse disc harrow for cultivation is not satisfactory on the type of soil at Amherst. Where cultivating is to be done with a tractor harrow, rows spaced eight feet are too close; rows spaced ten feet are satisfactory.

The summer of 1938 was very rainy. Except for a few spots where the soil is too wet in a rainy season, blueberry plants made very good growth. Rains interfered with the picking considerably, especially about the time that Rubel began to ripen. Many berries dropped before they could be picked, making yield records less reliable than in years of normal rainfall.

Studies of the relation between size of the bush and yield showed a high correlation between maximum spread (measured in one direction) and yield but a low correlation between maximum height of bush and yield. Since the latter is equivalent to correlating yield with the longest branch on the bush, the results are not surprising.

Experiments with honey bees as pollinators for blueberries were continued in cooperation with Dr. Frank Shaw of the Department of Entomology. Three aster-cloth tents were built, each covering two blueberry bushes of different varieties, and a nucleus hive of bees was placed under each tent. The set produced by the bees is compared in the following table with that of open-pollinated flowers and of branches covered with aster cloth to exclude insects. Varieties placed together in each tent are indicated in the table.

Variety	In Tents Bee Pollinated % Set	Open Pollinated % Set	Covered to Exclude Insects	
			Number of Clusters	Number of Berries
Cabot................	94.8	75.8	20	10
Pioneer...............	80.7	68.8	18	10
Pioneer...............	94.8		23	5
Jersey................	94.9	77.4	13	3
Pioneer...............	87.0		11	0
Rubel.................	93.8	89.4	30	9

The figures show that honey bees have again proved their value as pollinators of blueberries.

The hay mulch used in blueberry plot B seems to be very satisfactory except that it formed excellent cover for mice. Several plants were slightly damaged by mice during the winter of 1937-38. Anyone using a hay mulch should carry on a vigorous poisoning campaign in the fall.

Premature Dropping of the McIntosh Apple. (L. Southwick.) The September hurricane disrupted the experimental work, although valuable data were obtained prior to the storm. During the latter part of the season, daily growth measurements were made with an improvised circumeter, for the purpose of correlating growth rate with abscission initiation. Atmometers were employed for the first time this year to measure the evaporating power of the air at frequent intervals. The possible effect of this factor upon preharvest dropping will be studied.

Analysis of data up to this year warrant the following tentative conclusions regarding premature McIntosh drop. The evidence points to a complexity of interacting causes.

Premature dropping seems to increase in intensity from Massachusetts to the southern limits of the McIntosh belt; it does not decrease so markedly as the northern limit is approached. Dropping varies from year to year, from orchard to orchard, and from tree to tree in the same orchard. The problem seems to have become more acute in recent years.

Dropping was more severe with trees grown under a high state of fertility, and significant correlations were found between yield and percentage drop in most cases. Rootstock effect upon dropping severity was evident. This may help to explain wide variations among individual trees in an orchard.

Besides the secondary influence of wind, high maximum temperatures of even short duration in the harvest period hastened drop.

Seed number was positively correlated with time of drop. The many-seeded fruits not only hung better but were larger than those with few or no seeds. Seed number varied from 0 to 21 per fruit. Spur diameter, spur position, and leaf area were not found to exert significant influence, except that severe late-season defoliation caused increased abscission. Some evidence was found that long-stemmed apples dropped before those with shorter stems.

There are indications that strains may differ significantly in preharvest dropping behavior. At the present time it seems that this premise offers the most practical approach to the solution of the problem.

Sun Coloring of Apples. (O. C. Roberts.) In September 1937, experiments were started to study the effect of exposing poorly colored McIntosh apples to sunlight after harvest. Results of this initial experiment were reported in the Experiment Station report for 1937.

The experiment was continued during the summer of 1938. A wooden frame covered with two layers of 25 x 25 mesh cheesecloth was used. The experiment consists of four parts: (1) How early in the season color may be obtained by artificial methods; (2) the relation of sun scald to color development; (3) the number of hours of sunshine necessary to produce satisfactory color on normally uncolored fruit at harvest time; and (4) the effect of sun coloring on the keeping quality of the fruit. While no definite conclusions can be drawn from this experiment for the past season, there are a few trends that are worthy of note.

There is a tendency for apples picked prematurely to scald before acquiring satisfactory color. This tendency decreases as the apples approach maturity.

The time of exposure necessary to produce satisfactory color decreases as the apples approach maturity. When apples are fully mature, 30 hours of bright sunshine are ample to produce satisfactory color.

Sufficient color can be produced to admit apples to the fancy grade without turning them during exposure. Two layers of cheesecloth to provide shade during the coloring period appear adequate for the prevention of sun scald.

Exposure to conditions necessary for coloring does not seriously impair the keeping quality of apples when they are stored at 32° F. as soon as the desired color is obtained.

DEPARTMENT OF POULTRY HUSBANDRY

R. T. Parkhurst in Charge

Broodiness in Poultry. (F. A. Hays.) There are three major objects in this project: (1) To secure adequate data on the inheritance of degrees of broodiness, (2) to study the problem of deferred broodiness, (3) to establish a genetically non-broody line of Rhode Island Reds.

The generation hatched in 1937 and completing the laying year in 1938 was sired by two males that were 24 months old. These two males had the same sire and their dams were half-sisters. Male No. P467 produced 31 daughters with complete records from six non-broody dams. During the first year two daughters were broody, each from a different dam. This sire is indicated as having about 6.5 percent of broody daughters when mated to non-broody females. Male No. P911 sired from seven non-broody dams a total of 54 daughters with complete records. None of these daughters exhibited the broody instinct in their first laying year.

In the high fecundity experiments for the year 1937, 346 daughters have just completed their first year. Only 7 or 2.02 percent of these daughters have been broody.

A study of the last five generations indicates that deferred broodiness is not a significant phenomenon in hens after the completion of the second laying year. In this experiment the families of daughters from sires that gave no broodiness will be carried through their second laying year.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn.) Data have been tabulated and proposed for publication as follows: Time interval between clutches in Rhode Island Red Pullets, *Jour.Agr.Research* 57(8):575-582. The Absence of Linkage Between Genes for Early Sexual Maturity and Genes for High Persistency in Domestic Fowl, Paper for 7th World's Poultry Congress. Breeding Small Flocks of Domestic Fowl for High Fecundity, Paper for 1938 Meeting Genetics Society of America. Data have been completed for two bulletins.

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) From a foundation of exhibition stock from one breeder, eight generations have now been carried through a full laying year. The original stock was hatched in 1929. From this group of 45 pullets and 27 cockerels, an attempt has been made to develop two lines: one bred entirely for exhibition plumage color, and the other selectively bred for characters known to affect fecundity. The eighth generation showed a mean annual egg production of 150 and 175 eggs respectively for the two lines. Color remained satisfactory in both lines, fertility declined greatly, and mortality became excessive. No progress was made after the second generation. The data point to failure resulting from an attempt to breed for high fecundity with small numbers.

Rate of Feathering in Rhode Island Reds. (F. A. Hays.) An attempt is being made to establish an early-feathered line that shows complete back feathering at 8 weeks of age and a slow-feathered line that shows absence of back feathering at that age. The sires used in the first line had complete back feathering at 8 weeks of age, and the sires used in the second line had no back feathering at 8 weeks. In the fifth generation, hatched in 1938, 134 cockerels in the early feathering line showed 43 percent early feathered; and 39 cockerels in the late line showed 15.4 percent early feathered.

All chicks were classified for rate of feathering as shown by the presence or absence of tail feathers on the twelfth day. On this basis, only 3 out of 134 cockerels in the early line were early feathered; and none of the 39 cockerels in the slow line showed early feathering. These data indicate that the rate of feathering in the dorsal tract is not related to the appearance of tail feathers at 12 days.

No method has been developed for distinguishing between early and late feathered females.

Time of Emergence of Chicks from the Shell as a Factor in Poultry Breeding. (F. A. Hays and J. W. Locke.) Records have been secured on the time of emergence of about 2500 chicks. Observations were made during the hatching period at 8-hour intervals beginning at the end of the twentieth day of incubation and concluding when the chicks were taken from the incubator at the end of the twenty-second day. The relation between time of emergence and sex, mortality rate, body weight, and characters affecting fecundity are being studied.

Relation of Plumage Color to Sex in Rhode Island Red Chicks. (F. A. Hays.) A total of 6800 pedigreed Rhode Island Red Chicks have been described for brown and black pigment spots or stripes on head, neck, and back. The value of pigment areas for identifying sex at hatching and their relation to adult plumage color are being studied.

The Effectiveness of Selective Breeding to Reduce Mortality in Rhode Island Reds. (F. A. Hays.) Two lines have been developed by selective breeding: one selected for low mortality in the laying houses, and the other for high mortality in the laying houses. No other basis of selection was used in either line. In the first three generations there was a significant difference in mortality rates of the two lines. The fourth generation included too few birds to secure an accurate figure on mortality rates in the two lines. The mean annual egg records were 213 and 170 respectively.

Genetic Laws Governing the Inheritance of High Fecundity in Domestic Fowl. (F. A. Hays and Ruby Sanborn.) Major objectives in this project are as follows: (1) Developing a line genetically pure for sexual maturity in 180 to 215 days; (2) fixing high intensity so that winter clutch size will exceed 3; (3) eliminating all inherited winter pause; (4) eliminating the broody instinct; and (5) fixing genetically high persistency. Along with the above characters, fertility, hatchability, body size, egg weight, comb type, feather color, and inherited factors affecting mortality rate are all being studied.

The generation hatched in 1937 was particularly superior to previous generations in mortality rate in the laying houses and in freedom from broodiness. Without culling, the mortality rate for a full year was 12.5 percent. Only 2.02 percent of the birds became broody in this generation.

Genetic behavior of the characters being studied is constantly being checked by crosses with outside stock. Results from these crosses are regularly checked against the experimental line carried as such since 1913.

Miscellaneous Studies. (F. A. Hays.) In addition to the above projects, a number of other studies are being carried on. Among these are: Linkage relations between genes for comb type, ear lobe color, and shank feathering; artificial insemination with old males in cold weather; and molting behavior at the end of the first laying year and persistency of laying.

SEED CONTROL SERVICE

Philip H. Smith in Charge

Seed Inspection. (F. A. McLaughlin and Jessie L. Anderson.) From December 1, 1937 to December 1, 1938 the Seed Laboratory received and worked 2428 samples of seed, of which 1031 were collected by the State Commissioner of Agriculture and 1397 were sent in by seedsmen, farmers and the American Can Company.

Classification of these samples with the total number of tests involved is shown in the following summary. It will be noted that the total number of tests required for the 2428 samples was 3378; 859 for purity and 2519 for germination.

Samples		Purity	Germinatio
446	Field Crops for Purity and Germination	446	446
5	Field Crops for Purity Only	5	
7	Field Crops for Germination Only		7
143	Lawn Mixtures for Purity, Germinations involving 504 ingredients	143	504
71	Lawn Mixtures for Purity Only	71	
1	Lawn Mixture for Germination Only		1
1344	Vegetable Seeds for Germination		1344
152	Flower Seeds for Germination Only		152
194	Flower Seeds for Purity Only	194	
15	Tree Seeds for Germination Only		15
50	Tobacco Seeds for Germination Only		50
2428		859	2519

Field tests to determine trueness to type were conducted in cooperation with the Departments of Vegetable Gardening, Floriculture and Agronomy, which tested respectively 120 samples of vegetable seeds, 172 samples of flower seeds, and 23 samples of oats. All samples for these tests were collected and submitted by the State Commissioner of Agriculture, with the exception of ten samples of oats which were sent in by seedsmen.

Miscellaneous Work. (F A. McLaughlin and Jessie L. Anderson.) The Seed Laboratory cleaned 18 lots of onion seed and 42 lots of tobacco seed for Connecticut Valley farmers.

One hundred and seventy-six samples of corn, oats, barley, and wheat, purchased by various state institutions, were examined for conformity to grade purchased; and eighty-one samples of ground cattle and poultry feed, collected by inspectors or sent in by dealers and farmers, were examined microscopically.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint, and M. K. Clarke.)

1. *Pullorum Disease Eradication.* During the 1937-38 testing season a total of 314 flocks (including six flocks of poultry other than chickens), representing 502,341 samples (including 4,356 from fowl other than chickens), was tested. Among the samples submitted from fowl other than chickens 216 were also tested with paratyphoid antigen (*S. derby*). Blood samples were submitted from chicken flocks in 11 counties. Norfolk, Worcester, Middlesex, and Bristol Counties led in the number of tests. For the State as a whole, increases were observed in tested flocks (1), tested birds (31,708), tests (36,007), and non-reacting flocks (5). The average percentage of infection was further reduced from 0.37 to 0.17. Pullorum infection was detected in six flocks which were negative to the macroscopic tube agglutination test the previous year. The source of the infection could not be explained in four flocks. The detection of infection in previously non-reacting flocks emphasizes the value and importance of annual testing, as well as of effective preventive measures.

Testing results show that Massachusetts is in a position to replace its poultry population from 100 percent tested, non-reacting flocks. A total of 241 non-reacting flocks (100 percent tested), representing 432,919 birds, were identified in 11 counties. The flocks tested for three or more consecutive years revealed the lowest average percentage (0.07) of infection. Poultrymen are encouraged to buy only from flocks officially recognized as free from the disease.

Concerning fowl other than chickens, reacting birds were detected only among the turkeys.

During the past year this department has continued to cooperate in making available to the Massachusetts Department of Agriculture testing results which are used for official recognition and classification of pullorum tested flocks.

2. *Diagnostic Service.* The amount of material available for examination continued to show an increase. Personal delivery of specimens occurred in 352 of the 560 cases handled, which included 2,617 specimens. The classification of the specimens is as follows: 2,359 chickens, 172 turkeys, 19 canine feces, 15 pigeons, 9 rabbits, 8 pheasants, 5 bovine feces, 3 canaries, 3 canine skin scrapings, 2 each of bovine liver, canine, fox, goat feces, laryngotracheitis vaccine, mink, quail, ruffed grouse, and sheep, and 1 each of bovine placenta, canine tumor, feline parasites, fish roundworms, swine, and woodchuck. The diseases encountered most frequently were coccidiosis, pullorum disease, tumors, fowl paralysis, and avian encephalomyelitis (epidemic tremor). Presumably rare but important diseases were noted as follows: fowl cholera 3, fowl typhoid 2, paratyphoid infection 2, and avian tuberculosis 1. Each of these outbreaks represents a hitherto unknown focus of infection.

3. *Mortality Studies of Cottontail and White Hare Rabbits Imported into Massachusetts.* During the past year this department, in cooperation with the Massachusetts Department of Conservation, investigated mortalities among cottontail and white hare rabbits which were imported into Massachusetts. The cottontail rabbits were imported from Arkansas, Kansas, Missouri, Oklahoma, and Texas and the white hare rabbits, from Maine and Canada. Fifty consignments of dead rabbits were submitted to the laboratory from December to April inclusive. Among 2,415 cottontail rabbits imported, 213 were dead on arrival. The majority of specimens submitted were unfit for satisfactory examination. Coccidial oocysts were frequently observed in cecal contents. The following ectoparasites and endoparasites were detected: *Odontopsyllus multispinosus*, *Spilopsyllus simplex*, *Haemaphysalia leporis-palustris*, *Ixodes dentatus*, *Taenia pisiformis*, *Cittotaenia variabilis*, *Trichuris leporis*, and *Obeliscoides cuniculi*. No evidence of *Pasteurella tularense* infection was obtained from the gross pathology or animal inoculation. Papillomatosis was observed in several specimens. The majority of cottontail rabbits appeared to be in good state of nutrition.

Among 329 white hare rabbits imported, 15 were dead on arrival. In the specimens submitted to the laboratory two species of parasites (*Protostrongylus leporis* and *Obeliscoides cuniculi*) were encountered.

Appreciation is extended to members of the Zoological Division, Bureau of Animal Industry, United States Department of Agriculture, for identifying the parasites mentioned in this report.

4. *Infectious Bronchitis Immunization.* Infectious bronchitis is a virus disease which is of great economic concern to the poultry industry. The greatest loss suffered from the disease when present in mature birds is reduced egg production.

During the past year an outbreak of infectious bronchitis was investigated from the viewpoint of control by means of immunization with vaccine prepared from infected birds taken from the affected flock.

The vaccine was applied to the cloacal tissues. Susceptible and affected birds were inoculated and necessary control birds were retained both in the flock and at the laboratory. Definite positive cloacal reactions were not obtained with either the undiluted or diluted material taken from infected birds. However, positive transmission was obtained when the vaccine was inoculated intratracheally, intranasally, and into the conjunctival sac.

The methods employed did not induce an immunity to infectious bronchitis, since the disease manifested itself in the vaccinated flock after exposure of the vaccinated birds to the infective agent by introduction of the nasal and tracheal exudates into the respiratory tract and by means of cohabitation with infected birds.

It was concluded from the results that infectious bronchitis can not be prevented or kept under control in a flock through cloacal inoculation with the vaccine material as used in this investigation.

5. *Pullorum Disease in Turkeys.* In the routine testing for pullorum disease two infected turkey flocks were detected. Both flocks were subjected to intensive retesting. The testing results reveal that reacting turkeys may exhibit a great variation in agglutination titres. The agglutination reactions in many instances appeared indefinite and non-specific. Bacteriological examination of eggs laid by reacting turkeys revealed *S. pullorum.* This investigation is still in progress to determine the persistence of pullorum infection in turkeys and whether the disease can be transmitted through the egg as is the case in the domestic chicken. The macroscopic agglutination test is a valuable means of identifying turkey flocks which are free from the disease.

6. *Avian Encephalomyelitis Investigation.* Avian encephalomyelitis, commonly referred to as "epidemic tremor", appears to be increasing in poultry flocks in Massachusetts. The disease is infectious in character and is a malady of increasing economic importance. A preliminary report of the observations has appeared in the Journal of the American Veterinary Medical Association, Vol. 93 (N. S. 46), No. 6, 1938, p. 372.

7. *Viability of S. pullorum.* Viability studies, which are still in progress, show that *S. pullorum* has remained alive in a dry piece of cloth for a period of six years.

8. *Farm Department Brucellosis Control and Eradication.* The laboratory cooperated in this work by testing 753 bovine blood samples for Bang's disease and 73 porcine blood samples for Brucella infection. The standard tube agglutination method was used.

Studies of Neoplastic and Neoplastic-like Diseases. (Carl Olson, Jr.) Material for two transmissible neoplastic diseases of the chicken has been obtained from a small poultry flock in which 10 of 23 females died with neoplastic disease before reaching one and a half years of age. The disease became apparent in seven of these within a period of two months. Six of the cases of neoplastic disease have been tentatively diagnosed as lymphocytoma, two as erythroblastic leukosis, and one each as a hemangioma and neurogenic sarcoma. Upon inoculation of experimental birds with material from one of the birds spontaneously affected with erythroblastic leukosis, the same disease was reproduced. Material from a bird affected with what has been tentatively diagnosed as a lymphocytoma has given rise to a transmissible neoplasm which produces a tumor at the site of inoculation and in some instances metastases to the liver, kidneys, heart, pancreas, or proventriculus occur. This transplantable neoplasm of lymphoid character has been transmitted through 16 serial groups of experimental chickens. It is noteworthy that neither the agent responsible for the transmissible erythroblastic leukosis, nor that producing the transmissible neoplasm has given rise to reactions dissimilar to that which was found in the bird supplying the original material. This would seem to indicate that at least two disease-producing agents were responsible for the disturbances observed in the flock selected for study.

During the year 125 instances of suspected spontaneous neoplastic disease have been collected. This material is being studied to determine the relative incidence of neoplasia among chickens selected from various sources.

The study of tissue metabolism has dealt with the development of technic. Preliminary observations of the metabolism of both normal and pathological tissues have been made.

WALTHAM FIELD STATION

(Waltham, Massachusetts)

Ray M. Koon in Charge

The members of the research staff of the Waltham Field Station are assigned to the unit by the Department of Botany, Entomology, Floriculture, Horticulture, and Vegetable Gardening. Refer to the reports of these departments for results of investigations conducted at this branch station.

Consultation and Information Service. A definite increase was noted in the numbers of commercial vegetable growers, orchardists, florists, nurserymen, arborists, professional gardeners, greenkeepers and amateurs who came to the Field Station this year to personally consult members of the staff. The number of telephone calls for information on horticultural problems has increased to 4500.

Evaluation Gardens. A very comprehensive collection of 2485 herbaceous ornamental plants is maintained for the purpose of determining which varieties are of real garden value. In addition to their use for this purpose, the gardens have attracted 3785 visitors this year who, finding plants plainly and accurately labeled, have discovered a living catalog from which to select the best for their own home grounds.

The consultation service and the gardens bring increasing numbers of visitors to the Station yearly offering an exceptional opportunity for the members of the staff to acquaint the public with the more inclusive services of the Experiment Station at Amherst and the College in general.

Field Day. The attendance on Field Day, August 3, numbered about 1000, a slight decrease from that of last year. A prolonged period of rain terminated on August 2 which permitted the resumption of operations on the farm after a considerable interval. This accounts for the smaller attendance this year. Twenty years ago the first Field Day was held at the "Market Garden Field Station" in Lexington and 48 market gardeners went there to visit the experimental plots and vegetable variety trials and to witness the demonstrations conducted in their behalf.

Soil Testing Service. The demand for this extensive service is not decreasing, and it is hoped that the results will contribute to a better understanding of some of our soil fertility problems.

PUBLICATIONS

Bulletins

347 Annual Report for the Fiscal Year Ending November 30, 1937. 99 pp. March 1938.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

348 Control of the Begonia Leaf-Blight Nematode. By E. F. Guba and C. J. Gilgut. 12 pp. March 1938.

The culture of Lady Mac, Melior, and Marjorie Gibbs begonias represents a large enterprise in many floriculture establishments in Massachusetts. The leaf-infesting nematode is often a serious menace to the successful culture of these begonias. Sanitary and cultural methods within the limits of good plant growth and commercial practice are not effective in arresting the progress of the disease. Propagating from stock free of the leaf-blight nematode disease is the best measure of control. A method has been worked out for treating begonia plants by submersion in hot water, which has proved satisfactory in killing the nematodes. Besides a report of the experimental results, this bulletin contains detailed directions for using the hot-water treatment on a commercial scale.

349 Shade Tree Law in Massachusetts. By Edward T. Simoneau. 19 pp. February 1938.

The value of shade trees is recognized in Massachusetts, as is evidenced by the numerous laws enacted relative to their care. This bulletin sets forth the legislative history of the laws relating to shade trees, with a more detailed discussion of the present shade tree statutes and court decisions rendered. It is particularly useful to tree wardens and others who may be charged with the care and oversight of public shade trees in Massachusetts.

350 Tomato Leaf Mold as Influenced by Environment. By E. F. Guba. 24 pp. May 1938.

This bulletin deals with the various environmental factors which influence the development of the tomato leaf mold fungus and the infection of the tomato plant in the greenhouse, together with a comprehensive review of the pertinent literature. The disease is epidemic during the warmer months from June to October inclusive, when maximum greenhouse temperatures of 80° to 92° F. prevail; when the mean minimum inside and outside temperatures converge to narrow difference of less than 5° F.; and when the highest mean maximum relative humidity of 94-100 percent for the year prevails. The severity of the disease is related fundamentally to temperature.

351 Germination of Seeds and Damping-off and Growth of Seedlings of Ornamental Plants as Affected by Soil Treatments. By William L. Doran. 44 pp. May 1938.

Damping-off is a major problem in the propagation of plants from seed. It is not altogether controllable in practice by regulating and adjusting the environment (soil moisture, temperature, and reaction), for conditions favorable for the fungi are too nearly the same as those preferred by the plants. In washed sand or in a combination of sand and sphagnum or peat moss, there was very little damping-off as compared with that in soil. However, growth was always poorer in sand, even with fertilizer added, than in soil. Hence the search for better, safer, and less expensive soil disinfectants continues. This bulletin presents a summary of studies involving the use of a large number of chemicals and 112 species of ornamental plants.

352 The Carrot Rust Fly. By W. D. Whitcomb. 36 pp. May 1938.

This is a report on the history and distribution; host plants: injury caused; seasonal abundance; life history, seasonal history, and habits; and control of the carrot rust fly, which is the most destructive insect pest of carrots. Cultural practices which provide unfavorable conditions for development and reproduction are important factors in controlling this pest. Spraying or dusting carrots for pest control is not generally considered practical or economical in Massachusetts. Directions are given, however, for the use of materials which have proved successful in controlling the rust fly in case the value of the crop seems to warrant the expense of such treatment.

353 Leaf-Feeding Insects of Shade Trees. By W. B. Becker. 83 pp. July 1938.

The aim of this bulletin is to make available to the people of Massachusetts information regarding the habits and control of the more important insect pests defoliating the broad-leaved deciduous shade and forest trees. The insects discussed are those most commonly encountered, together with a few which have not yet been reported from Massachusetts but are to be found close to its borders. The description of the insects is accompanied in most cases by photographs of the insect in some of its stages or of the injury which it causes. The bulletin is particularly useful to tree wardens and others who are charged with the care and protection of shade trees.

354 Ascorbic Acid (Vitamin C) in Tomatoes and Tomato Products. By Walter A. Maclinn and Carl R. Fellers. December 1938.

Tomato ranks among the richest and most widely used of antiscorbutic foods. Sampling methods, reagents, and technique were studied in adapting the chemical methods to the problem of evaluating the tomato as an antiscorbutic. Effect of season, variety, maturity, storage, and other factors influencing the ascorbic acid content of canned and fresh tomato products were studied. Tomato varieties and strains showed a range of 74 to 249 international units of vitamin C per ounce. Commercial brands of tomato juice contained 40 to 100 international units per ounce, and a variation from 28 to 85 units per ounce was found within one brand.

Control Bulletins

92 Seed Inspection. By F. A. McLaughlin. 80 pp. February 1938.

93 Eighteenth Annual Report on Eradication of Pullorum Disease in Massachusetts. By the Poultry Disease Control Laboratory. 11 pp. June 1938.

94. Inspection of Commercial Feedstuffs. By Philip H. Smith. 68 pp. October 1938.

95 Inspection of Commercial Fertilizers. By H. D. Haskins. 51 pp. October 1938.

96 Seed Inspection. By F. A. McLaughlin. 102 pp. November 1938.

97 Inspection of Agricultural Lime Products. By H. D. Haskins. 9 pp. December 1938.

Meteorological Bulletins

589–600, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By C. I. Gunness. 4 pp. each.

Reports of Investigations in Journals

Numbered Contributions

276 Some correlations in plant-tissue composition, decomposition products, and effect upon crop rotation with tobacco. Walter S. Eisenmenger. Jour. Agr. Research 56 (4):309-316. 1938.

The plants studied for their effect on the tobacco crop were corn, timothy, redtop, ragweed, horseweed, and tobacco. The results indicate that plants containing the higher values of lignin, pentosans, high carbon-nitrogen ratios, and a subsequent low tendency to protein decomposition in soil may be suspected of being undesirable for tobacco rotation.

281 Galactose cataract in rats. Helen S. Mitchell and Gladys M. Cook. Arch. Ophthalmol. 19:22-33. 1938.

The discovery that cataract could be produced in rats by feeding a diet adequate in every respect, but supplemented with galactose, has led to the use of these animals in a study of the influence which other dietary factors may have upon lens changes. A low protein ration appreciably hastens the development of cataract and a high protein ration tends to retard it. Other dietary factors including excess or deficiency of certain relevant vitamins have failed to alter the cataract-producing action of galactose. The successive stages of development of the cataract visible to the naked eye are posterior opacity, dense nuclear opacity, and complete opacity. After a change to a normal diet, regression from the stage of complete opacity to that of dense nuclear opacity has been observed in a large proportion of the experimental animals.

283 A study of the types of problems investigated by graduate students in animal husbandry and the occupations in which the recipients of advanced degrees engage. Ralph W. Phillips and Frederick N. Andrews. Amer. Soc. Anim. Prod. Proc. 1937:182-188. 1938.

The data presented show the types of problems upon which theses submitted for advanced degrees in animal husbandry have been based, and were obtained from 31 of the Land-Grant Colleges. Totals of 508 Master's and 58 Doctor's degrees granted during the years 1930 to 1934 are included.

285 Nutritional anemia in cattle in southeastern Massachusetts. J. G. Archibald and K. J. Kucinski, and R. O. Brooke and S. L. Freeman. Jour. Dairy Sci. 21 (2):59-68. 1938.

A disease of cattle locally known as "neck ail," of long standing in certain localities of southeastern Massachusetts, has been shown to be identical with nutritional anemia of cattle occurring in various widely scattered portions of the world and known by various names. It is characterized by emaciation, loss of appetite, and a diminution of the red blood cells and hemoglobin content of the blood. It is caused by an insufficient amount of iron in the native forage which in turn is due to a very low iron content of the soil. As with cases reported from other regions, spectacular recovery has followed the administration of iron compounds to the affected animals. Addition of an iron compound to soils from the farms where disease occurred resulted in a large increase in percentage of iron in grasses grown on these soils.

286 Report on Zinc. R. A. Caughey, E. B. Holland, and W. S. Ritchie. Jour. Assoc. Off. Agr. Chem. 21 (2):204-207. 1938.

A method for the determination of zinc in plant products was worked out, and is described in detail in this article. The method shows practically a complete recovery between 5 and 25 gammas of zinc. For larger amounts of zinc, the use of suitable aliquots of the sample is recommended rather than the development of a different procedure. Further testing of the method by other laboratories is considered desirable.

287 Influence of bile and bile salts on *Aerobacter aerogenes*. James E. Fuller. Proc. Soc. Expt. Biol. and Med. 38:507-510. 1938.

The study was undertaken to investigate the premise of certain investigators that *Escherichia coli* may become *Aerobacter aerogenes*, and vice versa, as a result of environment. If the intestinal environment is capable of producing any such change, it seems that bile and its constituents would be likely factors in inducing these alterations. Thirty strains of *Aerobacter aerogenes* were propagated in media containing bile or bile salts for a period of five months. The results were in favor of the stability of the culture reactions of pure established cultures of *Aerobacter aerogenes* so far as the influence of bile or bile salts is concerned.

289 Erysipelas outbreaks in turkey flocks. H. Van Roekel, K. L. Bullis, and M. K. Clarke. Jour. Amer. Vet. Med. Assoc. 92 (n. s. 45):403-418. 1938.

Three spontaneous outbreaks of erysipelas encountered among turkeys are reported. These occurred in three widely separated flocks and at approximately the same time of year. No definite source of the infection could be found. Erysipelas infection in adult turkey flocks may cause serious losses in the form of mortality, retardation in growth, and less profitable marketing of carcasses for food consumption.

290 Some public health aspects of food. James E. Fuller. Jour. Amer. Dietet. Assoc. 14 (6):412-416. 1938.

The discussion is concerned with food-borne bacterial infections and intoxications in humans — ptomaine poisoning, food poisoning, botulism, and undulant fever. The organisms concerned, the frequency and seriousness of the infections, and some precautions which should be taken are all considered.

291 Species of Cladosporium on tomato and the allergic response in man as an aid to their identification. Emil F. Guba and Francis M. Rackemann. Mycologia 30 (6):625-634. 1938.

The results point to the fact that individuals allergic to fungi react differently to extracts of species in the same genus, and that this biologic test appears to offer another method by which closely related fungi may be distinguished one from another with considerable certainty.

293 The pollination of the cultivated blueberry. John S. Bailey. Amer. Soc. Hort. Sci. Proc. 1937:71-72. 1938.

Under Massachusetts conditions none of the varieties will set as well when self-pollinated as when exposed to pollination by insects. A few varieties will set a partial crop in some years, but self-pollination cannot be relied upon to give a consistently good commercial crop.

294 Storage changes in pascal celery. Robert E. Young. Amer. Soc. Hort. Sci. Proc. 1937:697-698. 1938.

The value of pascal celery on the Boston Market depends primarily upon the amount of heart growth that has taken place while the plants have been in the storage pit. There is a definite movement from the outer leaf stalks to the heart, and the outside leaves of the pascal celery plant are of definite value in the growth of heart stalks during storage. It would appear to be an advantage, therefore, in preparing the crop for storage, to leave as many leaf stalks on the plant as possible, removing only those which are damaged by frost and handling.

295 Yield-growth relationships in asparagus. Robert E. Young. Amer. Soc. Hort. Sci. Proc. 1937:576-577. 1938.

The most careful selection of crown at the time of planting will not eliminate the poor producing asparagus plants. It has been found that there is a high correlation between the number of spears produced and the number of stalks produced after the harvesting season. This is true for both male and female plants. Asparagus plant selection on the basis of summer growth is not in itself sufficient for the plant breeder, but it will give the producer of asparagus seed a method of plant improvement.

296 A statistical analysis of form variations in specific strains of tomatoes. W. H. Lachman, Eleanor A. West and Grant B. Synder. Amer. Soc. Hort. Sci. Proc. 1937:559-561. 1938.

Shape index (computed by dividing the average equatorial diameter of each tomato by its polar diameter) was used in a statistical study of variations in shape in 10 strains of tomatoes. There were no consistent changes in the shape during the season, although it was apparent that some varieties may be affected by more than genetic influences. The data showed that the 30 fruits used as a sample were sufficient to constitute a representative sample.

297 Further observations on a chlorosis of the cultivated blueberry. John S. Bailey and John N. Everson. Amer. Soc. Hort. Sci. Proc. 1937:495-496. 1938.

Experiments continued from the previous year gave some indication that the chlorosis might be due to a lack of iron. Further experiments with blueberries grown in pots under different conditions all lead to the same conclusion — that the chlorosis is caused by a lack of iron in the blueberry plant.

298 Malling stock influence on fruit size and shape. Lawrence Southwick. Amer. Soc. Hort. Sci. Proc. 1937:359-361. 1938.

Studies reported show that certain known rootstocks under McIntosh trees may be responsible, in part at least, for measurable differences in form and size of the apples produced.

299 Propagation studies with geraniums. Harold E. White. Amer. Soc. Hort. Sci. Proc. 1937:795-800. 1938.

Stem rot disease organisms are concerned in the losses of geranium cuttings. High temperatures at the time of propagating decreased the percentage of rooting and increased loss from stem rot. Stock plants grown under glass in benches yielded more cuttings and gave a higher percentage of healthy rooted cuttings than did field-grown plants. No other factors seemed to have any significant effect on the rooting of cuttings.

300 Factors affecting iron chlorosis in gardenias. Harold E. White. Amer. Soc. Hort. Sci. Proc. 1937:774-780. 1938.

Gardenia may be affected by different types of chlorosis. This particular type was definitely shown to be due to a lack of iron, and when severe, it may become a limiting factor of growth. The use of sodium or calcium nitrate induced iron chlorosis while nitrogen from organic or ammonia sources prevented it. Phosphorus and potassium had no influence on iron chlorosis, but sulfur even in quite small amounts prevented it. On the basis of experimental data, conditions other than soil acidity would appear to be contributing factors.

301 Relation of soil temperature to chlorosis of gardenia. Linus H. Jones. Jour. Agr. Research 57 (8):611-621. 1938.

The fact that a high soil temperature would dissipate a chlorosis of *Gardenia veitchii* suggested the testing of the effects of soil temperature on this plant. It was found that soil temperature not only induces and controls chlorosis of gardenia but also affects the above-ground parts in size of leaf, rate of growth, and alteration of the vegetative and reproductive phases, and even produces wilting when lowered to 10° C. or less. These findings indicate that soil temperature may have a greater effect on plants than has been commonly supposed and may even be more important than air temperature.

302 A method of pruning dead branches. James D. Curtis. The Forestry Chronicle Vol. 12, No. 3. 1936. (Reprinted in 1938.)

A new method of removing dead branches (of white pine) is proposed and described. So far as the formation of callus is concerned, the proposed method gives promising results after one year's growth. Further study is necessary before final conclusions can be drawn.

303 Carotene and ascorbic acid content of fresh market and commercially frozen fruits and vegetables. G. A. Fitzgerald and C. R. Fellers. Food Research 3 (1 and 2):109-120. 1938.

Feeding tests indicate that frozen products retain practically all their vitamin A during processing and freezing. Conditions of marketing frozen foods are conducive to complete retention of vitamin A up to the time of delivery to the consumer. Tests of several varieties of vegetables indicate that freezing has less influence on the amount of ascorbic acid (vitamin C) present than certain other factors, particularly maturity, soil, and climate.

304 Carotene content of fresh, frozen, canned and dehydrated spinach. D. DeFelice and C. R. Fellers. Amer. Soc. Hort. Sci. Proc. 1937:728-733. 1938.

Detailed directions are given for the determination of carotene in spinach and other vegetables and fruits. The method is reliable, not unreasonably difficult, and valuable for determining losses of carotene in foods during processing. Average carotene values converted into international units per gram are: fresh spinach 718, frozen 545, canned 481, and dried 495. Storage of canned or frozen spinach for 73 days had no effect on its vitamin content.

306 A study of rate of decomposition of haddock muscle at various temperatures as indicated by ammonia content. G. Chapman Crooks and W. S. Ritchie. Food Research 3 (6):589-598. 1938.

The rate of decomposition of ground fish muscle was satisfactorily measured by using the ammonia produced as an index of the protein decomposed. Haddock flesh containing 35 milligrams or less per 100 grams of muscle is normally sound and of good quality. Rate of decomposition was considerably retarded by lowering the storage temperature, and decomposition was apparently completely checked by holding the samples in a frozen condition. At a given temperature there was little significant increase in the rate of decomposition of ground, defrosted fish when compared with a similar sample which had not been frozen.

307 Time interval between clutches in Rhode Island Red pullets. F. A. Hays. Jour. Agr. Research 57 (8):575-581. 1938.

The relation of time interval between clutches to a number of fecundity and reproductive characters was studied. The various relationships observed led to the conclusion that, in a breeding program, short time intervals between clutches in winter should be placed along with short time intervals between eggs of a clutch as a desirable character.

308 Factors influencing the rate of decomposition of different types of plant tissue in soil, and the effect of the products on plant growth. Major F. Spaulding and Walter S. Eisenmenger. Soil Science 45 (6):427-445. 1938.

The object of the investigation was to establish by experimental methods principles by which the characteristics and relative values of natural fertilizers (humus) could be estimated in advance of use from their known or discoverable chemical constituents. A partial chemical analysis (including determinations of the proportions of nitrogen, carbon, lignin, and pentosans) was made of 43 different plants and 2 seed parts, and their decomposition studied under different conditions in the greenhouse. On the whole, the plants containing most nitrogen decomposed more readily. The structure of plants and their content of lignin and pentosans were also factors in the rate of decomposition. If the ratio of nitrogen to carbon was not more than 1 to 25-30, the plants decomposed easily, but if the ratio was wider, the incorporation of the plants in the soil resulted in a depression of the nitrates.

313. Preliminary report on infectious avian encephalomyelitis. H. Van Roekel, K. L. Bullis, and M. K. Clarke. Jour. Amer. Vet. Med. Assoc. 93 (n.s. 46): 372-375. 1938.

During the last few years the incidence of infectious encephalomyelitis in chickens apparently has increased. The geographical distribution of the disease is not known, but the greatest incidence has been reported among flocks in the New England States. The disease is caused by a filtrable, infectious agent. Field and laboratory evidence suggests that the infective agent may be egg-borne and that the breeding stock may serve as the reservoir of infection.

316 Diseases of nursery plants: Infectious and noninfectious diseases of evergreen and dedicuous trees in the open. Malcolm A. McKenzie. Amer. Nurseryman 68 (7): 3-4. 1938.

Noninfectious diseases discussed are needle blight, a disease of eastern white pine, and a disease caused by smoke. The cause of needle blight is not known, but the characteristic symptoms which differentiate it from other needle injuries caused by fungi or insects are described. Evergreens are more sensitive to smoke injury than are deciduous trees, but the latter may be affected. Several infectious diseases are discussed, with suggestions for the protection of nursery trees; and particular warning is given of the dangers of the Dutch elm disease.

323 Effect of riboflavin and thiamin chloride upon the cataractogenic action of galactose. Helen S. Mitchell and Gladys M. Cook. Proc. Soc. Expt. Biol. and Med. 39:325-326. 1938.

In previous work with galactose cataract the usual protective doses of vitamin supplements were provided in accordance with the recognized need of the rat. The normal growth of the rats and the lack of gross evidence of any vitamin deficiency led to the conclusion that the cataract was probably due to some metabolic disturbance unrelated to a vitamin. However, it was recognized that the introduction of galactose might have created unusual demands for certain vitamins. In this investigation riboflavin and thiamin chloride, two crystalline fractions of the vitamin B complex, were fed in varying amounts up to massive doses. Neither riboflavin nor thiamin chloride exerted any protective action against the development of galactose cataract in rats.

Unnumbered Contributions

Is soil temperature important? L. H. Jones. Florists' Exch. and Hort. Trade World. January 15, 1938.

Soil temperature important factor in chlorosis of gardenia. L. H. Jones. Florists' Review. February 10, 1938.

Control of apple scab after harvest. E. F. Guba. Mass. Fruit Growers' Assoc. Ann. Rept. 44:234-239. 1938.

Control of the begonia leaf blight nematode with hot water. E. F. Guba. The Florists' Telegraph Delivery News 37 (4):80-81. 1938.

The specificity of fungous allergy. F. M. Rackemann, T. G. Randolph, and E. F. Guba. Jour. Allergy 9:447-453. 1938.

Undesirable chemical reactions from the use of fungicides in greenhouses. E. F. Guba.

I. Florists' Review, January 13, 1938. p. 17.

II. Florists' Review, April 28, 1938. pp. 31, 68.

Combat elm disease. M. A. McKenzie. Amer. Nurseryman 67 (6):14-15. 1938.

Distribution of elm bark beetles in Massachusetts. W. B. Becker. Jour. Econ. Ent. 31:323. 1938.

Insect pests in Massachusetts orchards in 1937. A. I. Bourne, with W. D. Whitcomb and W. H. Thies. Mass. Fruit Growers' Assoc. Ann. Rept. for 1938.

The chemist's relation to insect control. A. I. Bourne. Mimeographed report of broadcast issued by Northeastern Section of the American Chemical Society, Inc. April 8, 1938.

The vitamin C status of college women as determined by urinary excretion. Helen S. Mitchell, Oreana Merriam, and Esther L. Batchelder. Jour. Home Econ. 30 (9):645-650. 1938.

Factors in milk influencing intestinal bacteria of infants. W. B. Esselen, Jr. Editorial, Jour. Amer. Dietetic Assoc. 14:271-273. 1938.

A frozen foods digest. C. R. Fellers and A. S. Levine. Quick Frozen Foods 1 (2):47-48. 1938.

Extension Publications

The following extension bulletins were prepared wholly or in part by experiment station men during the year ended November 30, 1938.

Printed

Raising the dairy calf. J. G. Archibald.

Pumpkins and squash. Paul W. Dempsey. (Revised)

Eastern tent caterpillar. A. I. Bourne and F. R. Shaw. (Revised)

Spraying and dusting fruit trees. A. I. Bourne, W. H. Thies, O. C. Roberts, and O. C. Boyd.

Mimeographed

Ants indoors. A. I. Bourne. (Revised)

Ants outdoors. A I. Bourne. (Revised)

Floricultural survey. Harold E. White.

Restoring hurricane damaged trees. M. A. McKenzie.

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